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IMPACTS OF OUTER CONTINENTAL SHELF ACTIVITIES: LAFOURCHE PARISH, LA.

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CONTINENTAL SHELF ACTIVITIES:

LAFOURCHE PARISH, LA.

Georgeann Happ
Victoria R. Bennett
Wm. W. Burke III
Wm. H. Conner
Nancy J. Craig
Robert E. Hinchee
James H. Stone
Leonard M. Bahr

Louisiana State University
Center for Wetland Resources
Baton Rouge, La. 70803

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ACKNOWLEDGMENTS

This final report from the Center for Wetland Resources, Louisiana State University, to the Louisiana State Planning Office, deals with environmental impacts of Outer Continental Shelf (OCS) activities on Lafourche Parish and Grand Isle, Louisiana. Objectives of the study were to identify environmental impacts of mineral extraction, navigation, and transportation projects and activities in Lafourche Parish and Grand Isle that result from OCS activity, and to measure the impact of these projects and activities.

This work was sponsored by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, through the Office of Coastal Zone Management. The activity is coordinated through the Louisiana State Planning Office.

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ABSTRACT

Three categories of activity were studied in relation to Outer Continental Shelf (OCS) development: they were mineral extraction, navigation, and transportation.

Mineral extraction encompassed exploration and production of oil and natural gas, pipelaying, and onshore support-facility siting. Described under navigation were ports and dock facilities, navigational canals, and shipyards. Land-based activities were implicit in the transportation category: siting and construction of highways, railroads, airports and heliports, along with associated landfill, muck disposal, and drainage practices.

Environmental impacts of OCS activities were described in terms of hydrocarbon discharge, altered drainage patterns, eutrophication, subsidence, erosion, direct land loss changes in salinity and turbidity, and disruption of flora and fauna.

In the petroleum industry, major sources of pollution are generally associated with refineries and petrochemical plants. Since none of these occur in Lafourche Parish, we conclude that the major environmental impacts of OCS activities are OCS employment-derived population increases, OCS use of pipeline ditches and navigational canals, and potential oil spills. Direct employment in Lafourche Parish as a result of OCS oil and gas production is estimated at 719 persons, with an induced support employment of 719 persons. Statistics from the Louisiana Department of

Commerce and Industry indicate a population increase of 3.2 persons for each industrial job created. Therefore, it is estimated that some 5,033 persons have been added to the Lafourche Parish population because of OCS development. Various environmental impacts can be ascribed to the needs, facilities, and services required by additional people. For example, land-use patterns are altered considerably to provide housing and recreation for that number of people. Similarly large tracts of land are occupied by industrial sites and offices that support the OCS activity. As an illustration of the support of population increase on public utilities, Lafourche Parish Water District No. 1, located in Lockport, processes and pumps water for Grand Isle and most of Lafourche Parish, excepting Thibodaux and the surrounding area. When the water plant was constructed in 1955, engineering studies indicated it would serve district needs until 1980. But, the facility has been tripled in size since 1955, and there is consideration of another expansion. The number of customers has increased from 5,118 in 1955 to 16,049 in 1976. Water consumption for a summer month in 1955 was 14,428,000 gallons, as compared to 143,184,700 gallons in June, 1976. Additionally, potential health hazards can be attributed to population growth. The rural parish has no sewerage system other than septic tanks in the 10th Ward (southern Lafourche Parish from Larose to Port Fourchon). The increased sewage load has reportedly caused raw sewage to stand in open fields and ditches during wet seasons.

OCS-use of oil and gas pipeline canals, and dredging of landfill, along with muck disposal, spoil banks, and potential oil spills, are other sources of environmental impact upon Lafourche Parish. Loss of primary production because of selected pipeline canals can be equated to $40,000 and $62,000 annually. Loss for selected natural gas pipeline canals ranges between $8,000 and $13,000 per year. Loss for navigational canals serving OCS activities may range between $36,000 and $56,000 annually. If a major oil spill occured in parish wetlands, it could take up to five years for the ecosystem to recover and the loss of net primary production is estimated to range between $41 and $68 per acre per year.

On the basis of the above preliminary data, we suggest the following guidelines for OCS-related activities: costs imposed by OCS activities on the air and water quality of the parish should be estimated. All pipeline canals should be restored as much as possible to their natural and original condition. All facilities no longer in use should be removed and the local environment restored to its original condition. All construction activities should be closely monitored for environmental hazards; this could possibly be done by means of a representative of the policy jury. Individual residents could supplement and aid this monitoring. New pipelines and navigation canals should be incorporated with other pipeline routes. Parish representatives should consult expert advice in regard to changes in drainage patterns, salinity, erosion, and turbidity. Urban and industrial development should be avoided in unmodified wetlands and carefully assessed in terms of its environmental impact. Discharges and litter from ships and automobiles should be prohibited. Parish officials should develop oil spill contingency plans for areas that are highly susceptible to this danger, such as those marsh areas close to the open Gulf. Estimates are made of the costs of implementing some of the suggested guidelines.

INTRODUCTION

Establishment of Louisiana's major Outer Continental Shelf (OCS) oil and gas use-activity impacts, and guidelines for mitigating these impacts, are necessary for rational management of the coastal zone. Impacts of onshore oil and gas activities need to be separated from those directly attributable to the OCS activity.

Studies and analyses of the impacts of OCS activities on the pilot study area of Lafourche Parish/Grand Isle are documented in this report to the Louisiana State Planning Office. The report contains six chapters, an introduction, and an abstract of the overall study; the introduction also contains a brief description of the study area; Chapter 1 describes OCS mineral extraction activities and related onshore support activities; Chapter 2 describes activities associated with OCS-related navigation; Chapter 3 describes activities associated with OCS-related transportation; Chapters 4 and 5 give a description and cost estimates of the environmental impacts of OCS development with a special emphasis on Lafourche-Grand Isle; Chapter 5 gives some suggestions for mitigating the problems.

Data sources included the files of the Center for Wetland Resources, the Louisiana State Planning Office, the Louisiana Department of Commerce and Industry, the Louisiana Department of Conservation, the Louisiana Wildlife and Fisheries Commission, the U.S. Geological Survey, and the U.S. Army Corps of Engineers. Additionally, visits to the Lafourche Parish area, and meetings there with civic, business, and political leaders were helpful, as were telephone conversations with representatives of private companies.

Description of the Study Area

Lafourche Parish is in southeast Louisiana, south-southwest of the city of New Orleans. The parish is accessible from the east and west via U.S. Highway 90; Louisiana Highway 1 provides a major north-south motor route. Rail facilities terminate at Valentine. Bayou Lafourche provides north-south waterway transportation to the Gulf of Mexico. The Intracoastal Waterway serves Lafourche Parish as an east-west waterway and is accessible from Bayou Lafourche. There is no airport facility in the parish, although development of an airport in the Ward 10 (South Lafourche) area is under consideration. Currently three heliport facilities support helicopter transportation to and from offshore oil facilities.

Grand Isle, a member of Louisiana's coastal barrier island chain, extends eastward from the southeast tip of Lafourche Parish and bounds the southwestern corner of Barataria Bay. Grand Isle lies within Jefferson Parish, but it is inaccessible by land except via Louisiana Highway 3090 through Lafourche Parish. In nearly every way--geographically, economically and culturally--Grand Isle is indubitably linked to Lafourche Parish.

Port Fourchon and Grand Isle (see Fig. 1) offer rapid access to the deep water of the Gulf of Mexico and serve as major transportation bases for OCS oil and gas development in Bay Marchand, South Pelto, South Timbalier, and Grand Isle fields, and to a lesser extent for the West Delta Field.

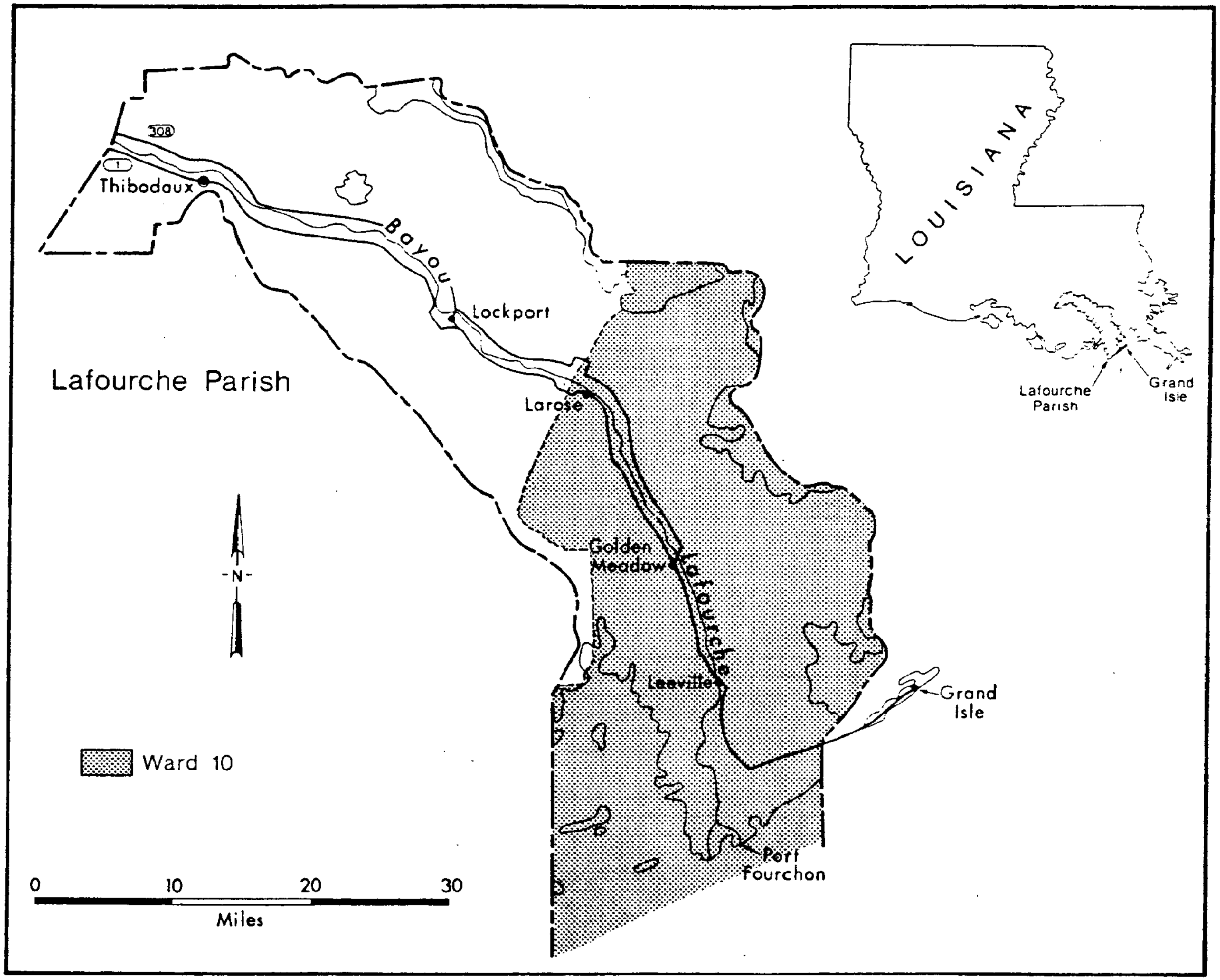


Fig. 1. Physical location of Lafourche Parish/Grand Isle study area.

Port Fourchon, administered by the Lafourche Parish Port Commission, is undergoing major expansion because of the need for more services for OCS development. The proposed Louisiana Offshore Oil Port (Superport) is planned for construction off the Fourchon coast.

The native citizens of the Lafourche-Grand Isle area are predominantly of French heritage. Many people in the area are bilingual. Historically, the economy of upper Lafourche Parish has been dominated by agriculture, with sugarcane being the major cash crop. Sugarcane farming and some commercial fishing and trapping have been historically important in the central portion of the parish. In the southern portion of Lafourche, the economy centered around commercial fishing and trap ping. Grand Isle was an important recreational and fishing center. As her economic history indicates, the Lafourche-Grand Isle area has always been rural.

Since World War II, the historical agricultural and fishing/trapping factors of the economy have become less dominant, because of the emergence of the oil and gas industry in the parish. Today only an estimated 6 percent of the work force of Lafourche Parish is engaged in agricultural activity. Another 16 percent is involved in a commercial fishing industry dominated by shrimping.

According to figures from the Louisiana Department of Employment Security, 8 percent of the Lafourche work force is engaged in mining (Table 1). Another 10 percent is involved in manufacturing and about that number is involved in manufacturing that supports the mineral and oil industry.

Table 1. Estimated work force in Lafourche Parish.

PARAMETER	NUMBER	PERCENTAGE OF TOTAL
Work force	20,000	100.0
Unemployed	725	3.6
Employed	19,275	96.4
Nonagricultural	14,775	73.9
Manufacturing	2,025	10.1
Construction	575	2.9
Mining	1,625	8.1
Transportation, Communication, & Utilities	2,500	12.5
Trade	3,050	15.2
Finance, insurance, real estate	425	2.1
Services, Misc.	2,200	11.0
Government	2,375	11.9
Other (shrimping etc.)	3,250	16.2
Agriculture	1,250	6.2

Note: Work force includes all employed whether those covered and not covered by Louisiana State Employment Security Laws.

Source: Louisiana Department of Employment Security.

An additional 12.5 percent of the work force is involved in transportation and related industries, largely associated with oil and gas development.

Population in Lafourche Parish has increased steadily since 1960. The 1960 federal census figure of 55,381 grew to 68,941 in 1970, a gain of 24 percent. That growth rate compares to a statewide rate of 11.9 percent. It is believed that the population of Lafourche Parish has continued to grow at a similar rate since 1970 although census data or other credible population data do not exist for this period.

Land-use charts of Lafourche Parish show that over 65 percent of the land area, 1,399 square miles, is vegetated marshland, range, and transitional land. The marshes of Lafourche are generally high in salinity, and consist of Spartina alterniflora (oystergrass or cordgrass). Mangrove, also common, is scattered throughout the Spartina marsh. Elevated spoil areas in the marsh stem from reclamation and oil-related activities and support a variety of shrubs and perennial plants.

Mammalian fauna consist of raccoon, nutria, mink, otter, rabbit, and species of rats and mice. Migratory waterfowl feed on widgeon grass, spike rush, and three square, produced in low salinity marshes; marsh subjected to high salinity supports almost no migratory waterfowl. A number of native species including mottled ducks, rails, blackbirds, and grackles occur year-round. Gulls, terns, herons, and shore birds utilize the beaches of the Gulf of Mexico in all seasons. Many migratory birds stop to feed or rest as they pass through the area to Yucatan and South America.

The quality of waters in the study area is affected by shipping and small boats, as well as effluents from the towns along the Bayou Lafourche. Contaminants include untreated sewage and trash fish dumped by shrimp trawlers. Fresh water entering Bayou Lafourche at Donaldsonville may be degraded in south Lafourche Parish by brackish water from connecting canals and bayous.

Sport fish in the Lafourche inhabit both the marshes and the Gulf of Mexico. Species include speckled and white trout, weakfish, redfish, croaker, flounder, bluefish, mackeral, cobia, jack-crevalle, and red snapper. Shrimp, crabs, oysters, and crawfish are commercially important shell fish (Gulf South Research Institute 1974).

CHAPTER 1

MINERAL EXTRACTION ACTIVITIES ASSOCIATED WITH OCS DEVELOPMENT

The boundaries of the OCS have not yet been defined to everyone's satisfaction. In Louisiana the location of shoreward boundaries is disputed, although in 1956 the federal government and Louisiana recognized zones extending seaward from the Chapman Line (a line following the Louisiana coastline, established for administrative convenience). Zone One consists of the area three miles seaward from the Chapman Line; Zone Two extends from the seaward limit of Zone One to a line three marine leagues from the Chapman Line; Zone Three consists of the area seaward of Zone Two to a line three marine leagues seaward from the "Coast Guard Line"; and Zone Four comprises all submerged lands seaward from Zone Three to the undefined limit of the OCS. Louisiana has jurisdiction over Zone One. Portions of Zones Two and Three are in dispute. The remaining undisputed area of Zones Two and Three, and all of Zone Four belong to the federal government (U.S. Dept. Interior 1975).

From 1954 through 1974, 1,578 leases were granted on Louisiana OCS; the total for the United States OCS was 2,384. Louisiana's OCS production has thus been a major source of fuel for the rest of the nation.

Mineral extraction on the outer continental shelf requires both offshore and land-based facilities. There are many activities associated with exploitation of OCS resources. In the exploration phase, permits must be obtained, geophysical surveys carried out, leases acquired, rigs and platforms set up, and wells drilled. Once production is underway, additional wells must be drilled and completed. To transport the hydrocarbons to the shore, pipelines are laid across the ocean bottom. Onshore pipelines carry the hydrocarbons to facilities such as refineries and processing plants. Other transportation systems are required for workers and supplies, including highways, railways, airways, and waterways. If necessary, new routes are established. In many instances, creating new transportation routes has an impact on the coastal zone. For instance, inshore dredging of new channels destroys marshland. Additionally, spoil deposited on canal banks prevents natural water exchange in the marsh.

Exploration

Before any OCS exploration can be performed, a permit must be obtained from the Area Oil and Gas Supervisor of the U.S. Geological Survey (USGS) (Fig. 2).

The permit is granted after it is determined that the requirements of the Department of Interior and Louisiana have been met. (This permit does not include the right to take bottom samples or cores. Additional permits for these activities may be obtained from USGS.)

The U.S. Army Corps of Engineers must also issue a permit to the applicant after determining that navigation routes will not be obstructed. The company must file an agreement to comply with all regulations of any adjoining state that governs and restricts the exploratory techniques to be used. This stipulation is intended to protect and conserve

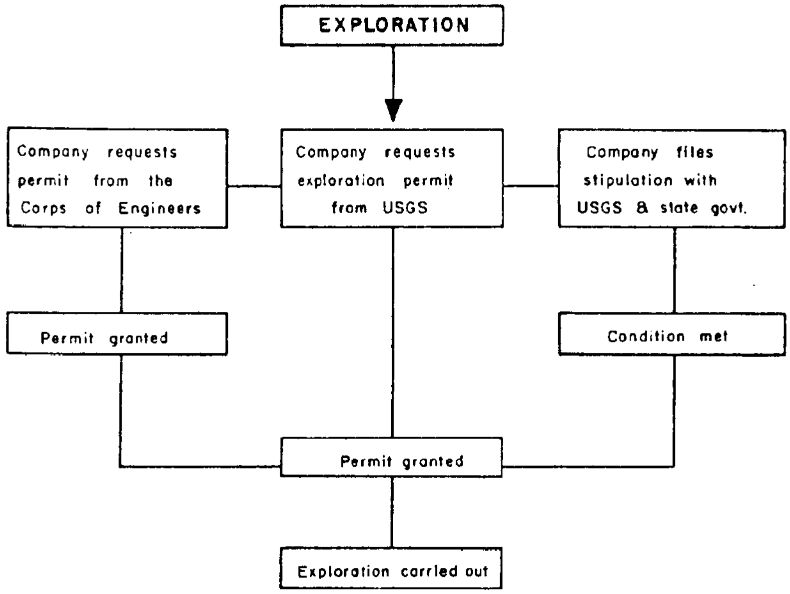


Fig. 2

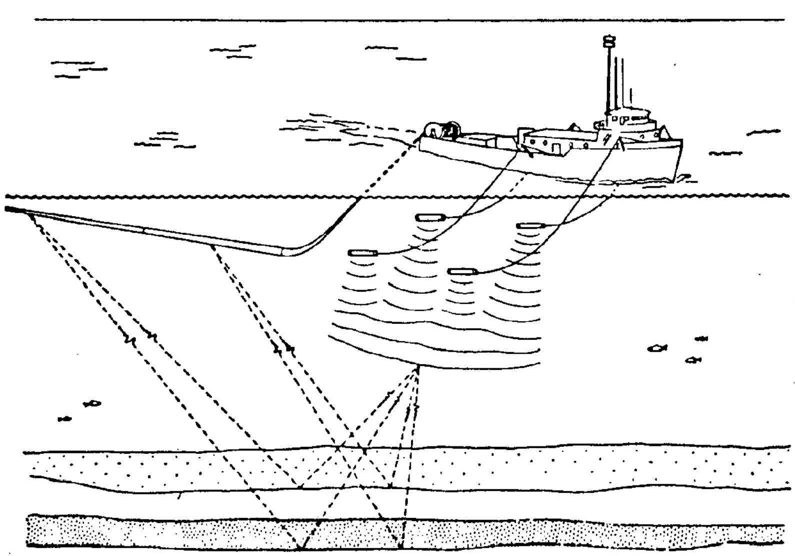


Fig. 3

Fig. 2 (above). Exploration procedures.
Fig. 3. **Seismic surveying with continuous electronic vibration** (Kash et al. 1973).

aquatic life. Pollution, the use of explosives, and obstruction to fishing are covered under cooperative agreements among the National Marine Fisheries Service (NMFS), the Bureau of Sports Fisheries and Wildlife, the Bureau of Land Management (BLM), and the USGS.

The search for offshore oil or gas begins with seismic surveys (Fig. 3). Acoustic waves are generated that penetrate deep below the ocean bottom. The waves are reflected from successive rock formations back to the surface where they are picked up by detecting devices and recorded. By measuring the time intervals required for the impulses to travel down and back and analyzing and interpreting the data, a geophysicist can determine the geometric configuration of formations that lie underground, including possible locations of oil or gas deposits. A device has been designed to replace the use of dynamite in creating seismic shock waves under water. A mixture of propane and oxygen is ignited inside a rubber sleeve. Rapid combustion instantly inflates the sleeve like a balloon and produces a seismic pulse. The device is apparently noninjurious to marine life and is more economical to use than dynamite (Exxon USA 1972).

If geophysical and geological studies indicate locations where oil or natural gas may exist under the ocean floor, the companies proceed to nominate tracts that they would like to develop. After consulting the USGS, the BLM holds public hearings and develops stipulations for individual tracts. Following the preparation of an environmental impact statement by the BLM, a public hearing is held to discuss the draft. The environmental impact statement is finalized, USGS evaluates the tracts, and the BLM prepares a sale notice, which the Secretary of Interior must approve. The notice is published in the Federal Register thirty days prior to the sale (Figs. 4 and 5). Interested companies may submit bids to BLM, which, on recommendation of the USGS, awards leases (Kash et al. 1973).

Upon obtaining a lease, the company drills an exploratory well, using a mobile rig. Three general types of mobile rigs are used in exploratory drilling: one is the self-elevating rig that can be towed to location. At the drilling site, the legs are lowered to the seabed and the platform is jacked up to a safe level above the sea. Current "jack-up rigs" work in waters up to about 300 feet deep.

Another type of rig is known as semisubmersible. One of these can displace as much as 20,000 tons and cost over $20 million to construct. Some of the semisubmersibles can actually sit on the bottom in shallow waters, but they are more frequently used in a partially submerged position and moored by anchors much like a ship. To keep such a rig aligned directly over a well, mooring lines may extend out a mile or more. At the end of each line is a massive anchor, weighing as much as 30,000 pounds. An elaborate acoustical system with a sonar computer shows the exact position of the rig relative to the well. Several semisubmersibles have drilled wells in water 600 feet deep, and some are designed for depths beyond 1,000 feet (Exxon USA 1972).

A third type of rig is the floating drill ship. This is a ship with a hole literally cut through the hull for drilling. It is moored in the same manner as a semisubmersible although recently some drill

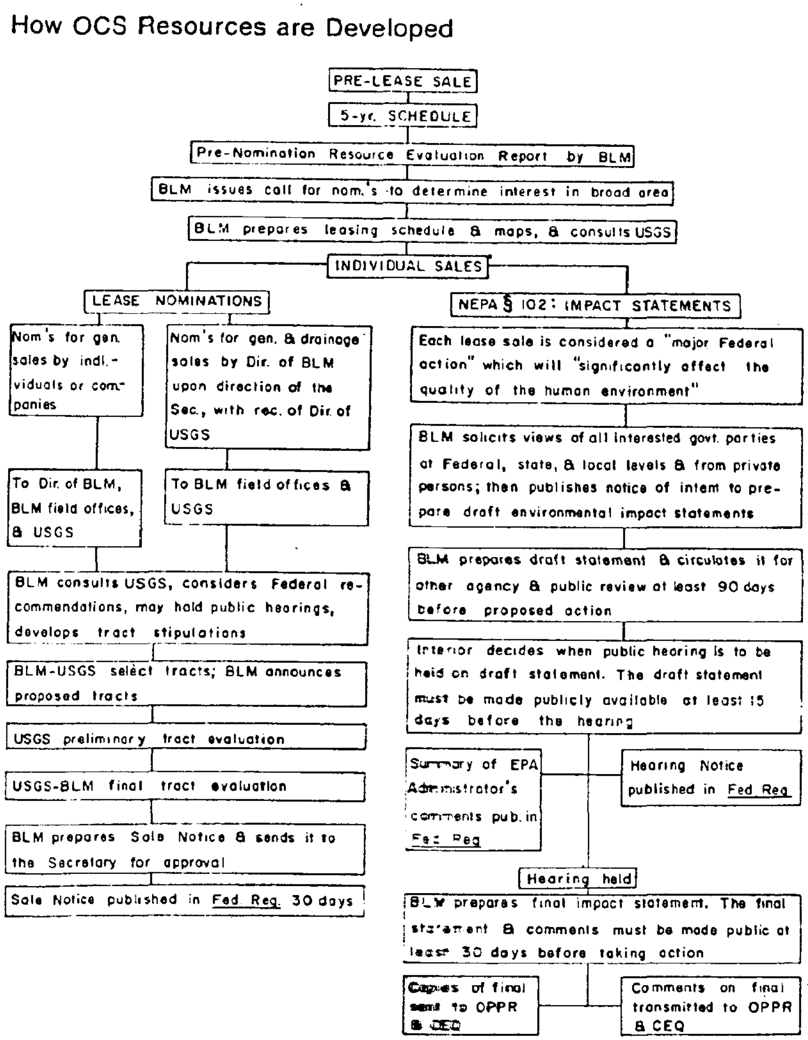


Fig. 4. Pre-lease sale procedures. (Kash et al. 1973)

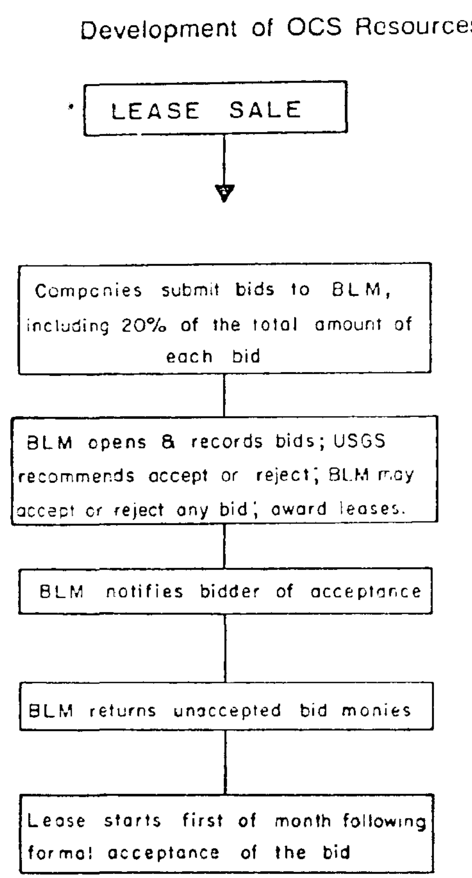


Fig. 5. Lease sale procedures. (Kash et al. 1973)

ships have been built that employ propellers and thrusters to maintain position. Drill ships have been used in waters a thousand feet deep (Exxon USA 1972).

Rotary drills are used offshore. The rotary system employs a gear-driven turntable that rotates the entire drill string as it bores through the formations. A cutting bit is attached to the lower end of a continuous column of steel drill pipe. The upper end of the drill string is attached to a square steel "kelly bar," which travels through and is rotated by the turntable (Stevens and Cyrus 1941).

The rotary system of drilling requires circulation of drilling fluids to keep the bit clean and to remove cuttings from the bottom of the hole. Drilling fluids are pumped from the surface through the hollow drill pipe to the bit and the bottom of the hole and circulated back to the surface through the annular space outside the drill pipe (McCray and Cole 1959).

As drilling progresses and the hole is deepened, it is necessary to add more drill pipe. The usual practice is to break the kelly loose from the drilling string, swing it over and make connection to a joint of drill pipe. After connection is made the joint is connected to the drilling string and drilling resumes. Also, it is necessary from time to time to withdraw and stack the entire drill string in order to change bits, perform down-hole logging surveys, and various completion operations.

It is customary to core in order to locate the exact top of the producing formation and to determine its fluid contents. If it is believed necessary, a drill stem test may be made to determine the producing characteristics of the formation. When the producing formation has been penetrated the desired amount, the drill pipe is withdrawn from the hole. An electrical log of the formation may be taken (Stevens and Cyrus 1941).

If oil or gas--or both--are found in commercially significant quantities, preparations are made to change the platform from drilling to production operations. Once drilling is completed, production casing is run into the hole and cemented in place. An additional, smaller pipe, called "tubing," through which hydrocarbons are to flow, is usually suspended within the innermost string of casing from an assemblage of valves and other equipment at the wellhead. If several producing horizons are penetrated by the same borehole, separate production tubing may be run to each such horizon. Such a system is termed a multiple completion. The wellhead assembly is called a "christmas tree"--an assembly of valves, controls, and connections designed to regulate the flow of fluids from the well.

Downhole safety valves are installed in the tubing string below the ocean floor. These devices are designed to automatically shut off the well when flow pressures vary from predicted norms. Some of the valves are designed to be operated from the surface. Other safety devices include automatic and manually operated valves, alarms, and monitoring and recording equipment. Navigational warning and fire detection devices are also installed. Master switches, located at various places on the rig, are designed to shut down the entire operation if an emergency should occur that might endanger life or property or cause an oil spill (American Petroleum Institute 1976).

In areas where oil or gas is found to be economically producible, platforms to drill development wells are installed. These platforms are huge, fixed structures that can be installed in hundreds of feet of water. Like the mobile rigs, they are large enough to contain living quarters for the work crew, a helicipter landing pad, storage space for supplies, and room for the drilling and production equipment. The typical platform is so designed that thirty or more wells may be drilled from the same location through use of directional or angular drilling. Thus wells drilled from a single platform may extend over several hundred acres as measured at the bottoms of the holes.

The design and construction of offshore structures are an integral part of the efforts to protect ocean environment. Extensive research studies have been made of the effect of water depths, tides, shifting currents, and wave and wind forces during storms to insure that offshore drilling and production platforms can withstand these elements.

The offshore structures now in use in the deep waters of the Gulf of Mexico have been built to endure winds up to 140 miles per hour and waves of 60 feet (Exxon USA 1972).

Despite all precautions, blowouts do occur occasionally. There are a number of ways to deal with a blowout, but the operator normally would first try to shut off the well with existing valves or other control equipment. If existing equipment cannot be used, replacement equipment may be tried. In some cases, heavy casing with valves is lowered into

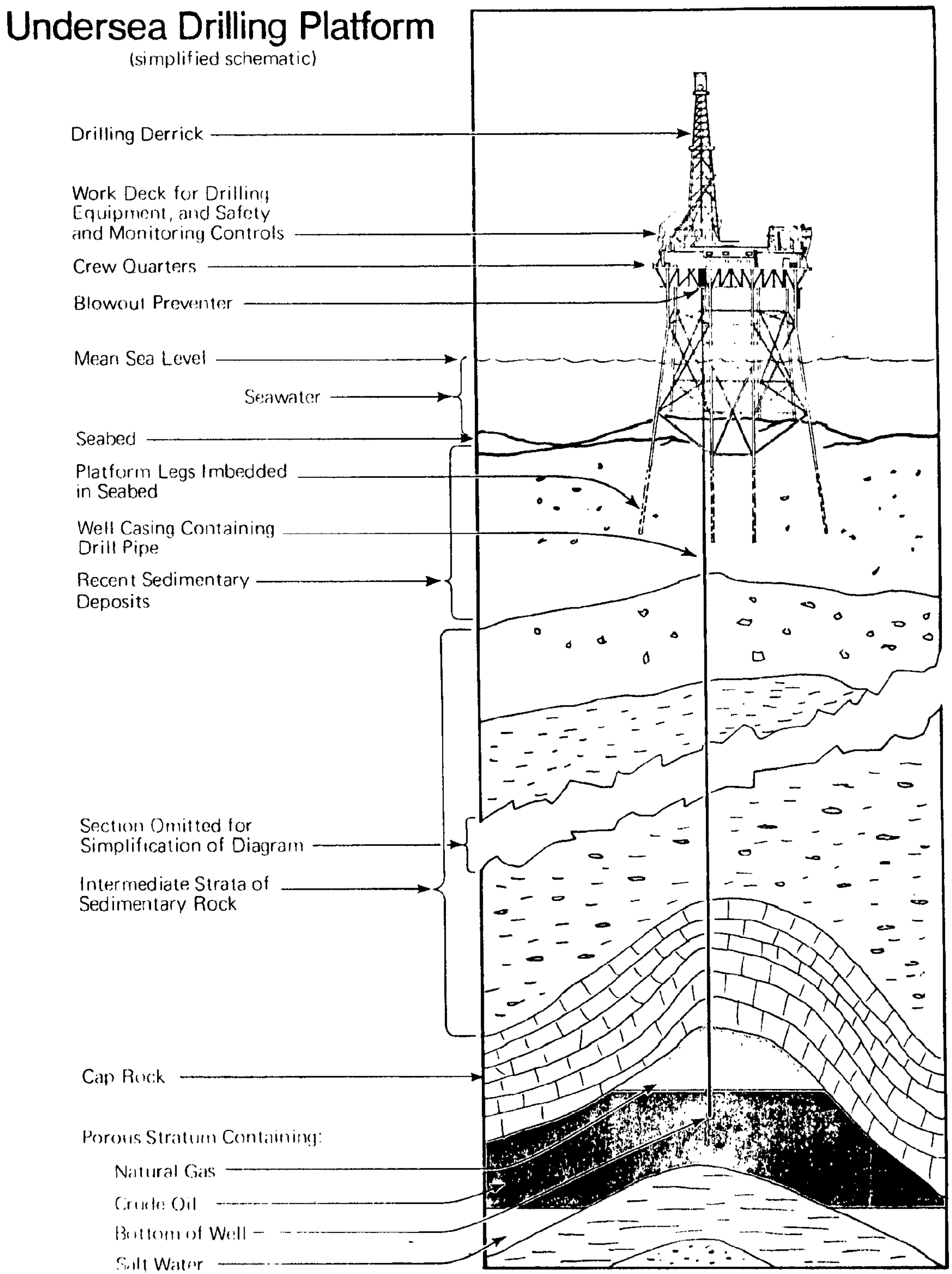


Fig. 6. Undersea drilling platform schematic (API 1976).

place over the wellhead, and the flow of oil and gas continues through the valves. When the casing is securely fastened, the valves are closed one by one until the well is under control. These control methods can sometimes be carried out in a matter of a few hours. If for any reason the wellhead cannot be capped, the usual procedure is to drill a relief well. To do this, a rig is moved to a nearby spot and a directional hole is drilled to almost intersect the bottom of the blowout well. Then mud is pumped into the underground reservoir under high pressure, stopping the flow. This is a difficult and time-consuming procecure that might take weeks.

Pipelines provide the predominant method of transporting hydrocarbons to shore. Three techniques are used in pipelaying offshore, denoted as: lay barge, reel barge, and pull pipe. Of the three methods the lay barge technique is the most common. Sections of pipe, which are usually coated with concrete, are welded together on a lay barge and lowered into the water as the barge proceeds forward. Lay barges have been used to lay pipe ranging in diameter from 4 to 52 inches.

The reel barge method emplaces long sections of pipe that have been welded together on land and wound onto the large reel upon the barge. Use of reel barges is limited to pipe less than 12 inches in diameter, and offers the most economical method of pipelaying in the 4 to 10 inch diameter range.

The pull pipe method involves making up the pipe onshore and then pulling it offshore to be connected at the rig. Because of frictional drag stresses on the pipe, pipe can only be pulled two to four miles offshore.

Current practice is to bury pipelines for their protection. A burial barge is used to sink the pipe beneath the surface, usually displacing soil with a wake of a high pressure water nozzle which jets bottom soil into suspension.

Offshore pipelaying operations are greatly affected by weather and sea state. Where conventional equipment is in use, operations usually are shut down if the waves attain a height of six feet or more (Kash et al. 1973).

Water depth is a limiting condition in pipelaying offshore because of diver and structural limitations. Diving depths are being extended by the use of a full saturation system and a diving bell, and efforts are being made to develop diverless systems for deep waters. In order to support the pipe between the barge and the ocean floor, lay barges use an articulated structure with a "stinger" (adjustable buoyancy). An inclined or vertical assembly area for pipe is also used for increased depth capability.

Pipelines carry about 75 percent of the state's petroleum commerce. They are important parts of the petroleum companies' oil field development programs. The pipeline network of coastal Louisiana is extensive.

Onshore, pipe is laid in canals dredged by a floating excavating machine of either a bucket or hydraulic type (McGhee and Hoot 1963). Of the two, bucket dredges are the more useful in performing initial channel excavations in marsh or swamp areas. Both types of dredges are used in channel maintenance.

Bucket dredges employ a dragline permanently fixed to a barge-type hull. The barge is equipped with three or more spud piles that can be thrust into the bottom to position the barge during operation. Typically, the dredges are equipped to work with a six to eight cubic yard clamshell-type bucket (Gagliano 1973). After excavating channel material by biting or digging into the bottom, the bucket is raised clear of the water. The spoil is dumped into waiting scows or self-contained hoppers, or placed along the banks (Simon 1920). Bucket dredges usually leave a continuous embankment of spoil along one or both sides of the excavation. Sometimes spoil is placed in reaches alternating from one bank to another in order to minimize the impediment to natural sheet flow across the marsh. Spoil bank dimensions depend on the size of the excavation, the length of the boom, and the stability of the canal and spoil banks (Gagliano 1973).

Problems may occur when the dredge is digging clay or sand. Clay is difficult to dig, and sand tends to filter through the bucket, reducing efficiency of the equipment. However, these are only minor problems (Davis 1973).

Where maintenance of access canals is necessary, hydraulic dredges may be used. They are also used at major stream crossings and in open water. Hydraulic dredges cut into the water bottom with a large rotating cutter head supported on a long suction pipe. Earth dislodged by the cutter is sucked into the pipe and pumped to a spoil-retention area. Suction-dredged spoil is left in several characteristic patterns. Most typically, it is deposited in small hillocks or mounds in the vicinity of the tail pipe where the slurry is discharged. These mounds are usually along one margin of the dredge cut. Since the tail pipe is moved only periodically, the embankment formed by this type of spoil is often discontinuous. Sometimes in large jobs suction-dredged spoil is impounded by dikes. This is done where it is desirable to build an embankment or elevated area for construction, or when the material is to be used as future borrow material (Gagliano 1973).

The hydraulic dredge is an extremely efficient excavating tool. However, there are problems such as:

1) Stumps, logs, and other trash that is hard to pass through centrifugal pumps;

2) Pockets of gas entrapped in the material that causes severe cavitation and turbulence in the pumping system;

3) Job locations in areas that are difficult to reach; and

4) Extremely stiff clay soils, which are both difficult to cut with the dredge cutter head and hard to pump because of the weight of the material (Davis 1973).

Two other machines that can be used in at least one phase of pipe-laying are the spud barge and the marsh buggy dragline. Spud barges differ from bucket dredges in that the dragline is not permanently fixed to the barge. The spud barge is especially effective because the drag-line can either be secured to the barge or operated on land on its crawler tracks. This versatility is invaluable in such jobs as clearing swamp locations and laying pipeline river crossings. Since the dragline is not fixed to the barge, the boom is shorter and the bucket is smaller than those usually found on bucket dredges. However, as in the case of the bucket dredge, a spoil bank is made immediately adjacent to the canal (Gagliano 1973). In Louisiana's wetlands, a two and a half cubic yard bucket is about the largest employed in channel work.

The marsh buggy dragline consists of a dragline mounted on motorized, tracked vehicles equipped with large flotation pontoons, similar to those used to carry seismic equipment through marsh. Their usefulness is limited primarily to marshy terrain as they do not operate well in deep water or stump-clogged swamps. By simply cutting a ditch for floating in the pipe, it eliminates a full-scale canal to accomodate the pipeline-laying barge. While this type of operation produces far less spoil than previously described methods, marsh buggy tracks often cause pronounced changes in the marsh surface, particularly in areas of floating vegetation where the mat may be permanently damaged (Gagliano 1973).

Pipeline is laid by the dry land, "push ditch" or "shove," or the flotation method. With the dry-land method, a right-of-way is cleared of all vegetation, a ditch is dug, and the pipe is welded, fabricated, lowered into the ditch, and buried in place. The right-of-way is generally 125 feet wide and the ditch is usually about 8 feet deep. Once the pipeline is completed, the ditch is backfilled and the previous use of the area (e.g., agriculture) is resumed (Stone 1975).

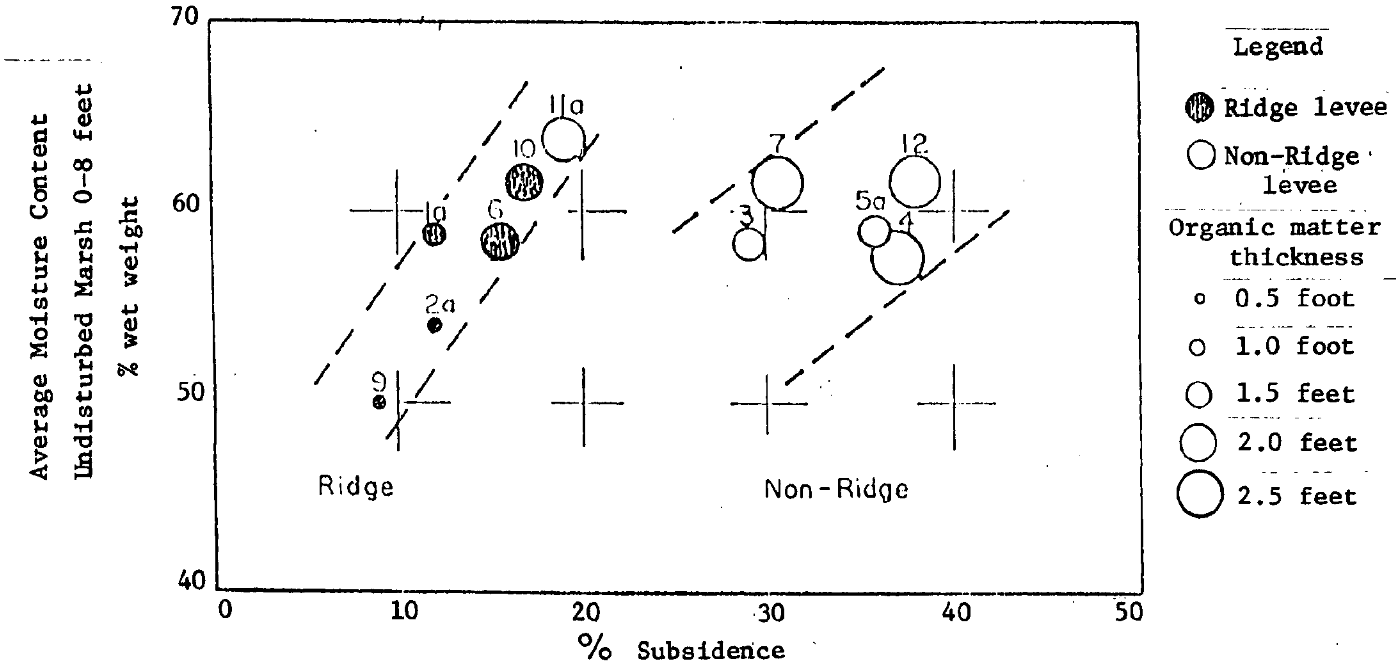
The "push-ditch" or "shove" method is used only where the marsh is firm. A narrow, relatively shallow ditch is excavated from the bank by a dragline or clamshell digger. By using a marsh buggy base or by using runners or pads to spread the weight, damage to the bank is minimized. The ditch may be 4-6 feet deep and 8-10 feet wide. The pipe sections are joined together at the point of origin of the ditch. To give it temporary buoyancy, the line is strapped to floats, then pushed or shoved down the ditch. A section as long as 15 miles can be installed in this fashion. After the line has been floated into place, the floats are cut loose to allow the line to sink to the bottom of the ditch. Typically, approximately 4 feet of water covers the pipe. The ditch may be left open but is more frequently backfilled. Even in firm marsh, there is generally sufficient subsidence or shrinkage such that the spoils do not completely fill the ditch. However, usually no canal is left after completion (McGinnis et al. 1972). A right-of-way of about 150 feet is usually required to lay the pipeline (Stone 1975).

In the flotation method of pipelaying, the pipeline is constructed on a series of lay barges and passed over the stern of the train. The pipe is large and heavy, requiring massive equipment to manipulate it. For example, a standard 40-foot section of 26-inch pipe weighs approximately 4 tons. When a corrosion coating and 3-4 inches of concrete are added to it, a 40-foot section weighs about 17 tons. Equipment to handle weights of this magnitude cannot be supported by the marsh, so a flotation canal provides access for the pipelaying equipment. Such a canal may be 40-50 feet wide and 6-8 feet deep; it may have an additional trench in the bottom to provide 10-12 feet clearance above the pipeline. Usually, the canal is excavated by a barge-mounted bucket dredge.

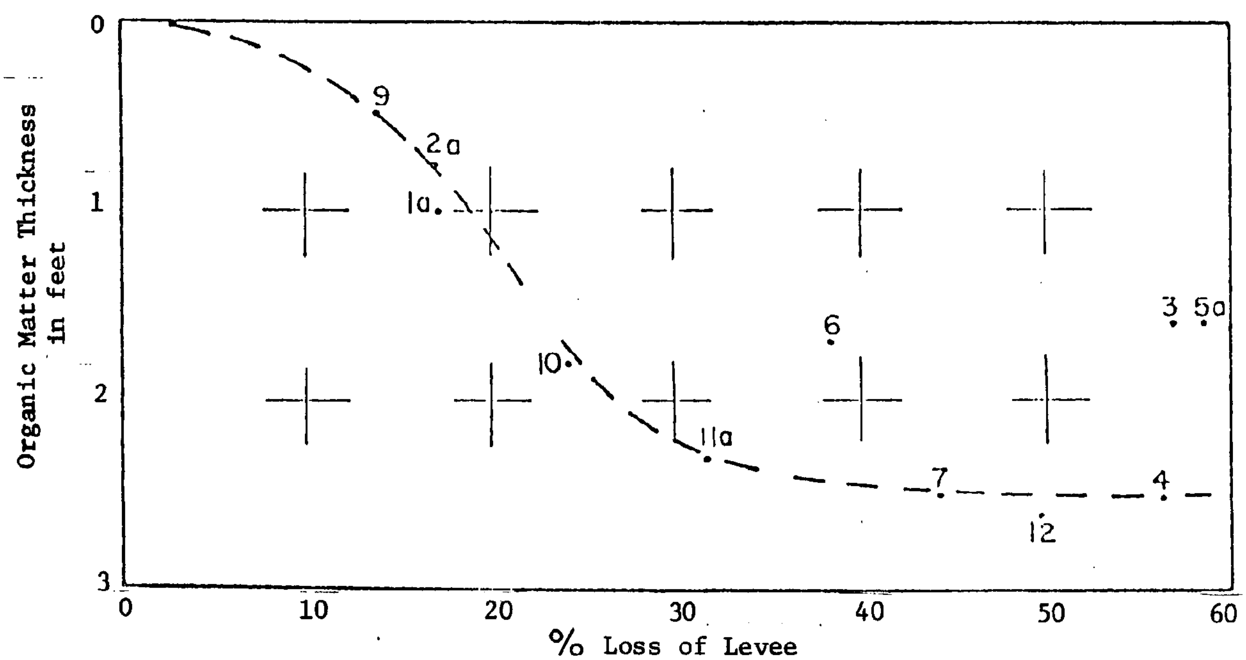
The flotation technique requires a right-of-way of about 300 feet (Stone, in press). The flotation dredge normally piles the spoil on each side of the canal to form a low levee. Generally, the spoil is set some distance from the canal to leave a 30-40 foot berm between the canal and the levee. Depending upon both the amount of material excavated during canal construction and the stability of the spoil, a levee may be 3-5 feet high and possess a base width of 50-85 feet.

Treatment of completed canals, whether of push or flotation type, is a matter of negotiation between the pipeline owner and the owner of the land being traversed. Landowners may require bulkheads, plugs, or dams wherever a canal intersects another waterway in order to minimize erosion and prevent navigation traffic, which is a prime cause of erosion (McGinnis et al. 1972). Where canals traverse state-owned land or wildlife refuges, very stringent conditions may be attached to the right-of-way grant with the objective of minimizing impact on the territory. These conditions may include backfilling a flotation canal. However, the high water content (50 to 80 percent) and the organic nature of the excavated muck lead to major shrinkage and subsidence when piled on top of marshland with similar properties (Fig. 7). Height reductions of 50 percent are possible (Nichols 1959). Because of the shrinkage and subsidence, there is never enough spoil from the excavation for the backfilling to be completed. In one recent example, nearly 2 miles of flotation canal crossing a wildlife refuge were backfilled. However, an additional backfill (nearly 160,000 cubic yards) had to be dredged from a nearby bayou and lake as insufficient spoil material was available. Backfilling with foreign material on a large scale is probably economically infeasible, and the environmental impacts of the additional dredging required are extensive.

If access canals are not filled, spoil banks are left on the sides of the channels. Spoil banks, or levees, are embankments created from



a. Relationship between levee loss, organic matter thickness, and average moisture content of the undisturbed marsh from the surface to a depth of 8 feet.



b. Relationship between levee loss and organic matter thickness

Fig. 7. Levee loss as related to organic matter thickness (Nichols 1961).

material dredged during channel construction. This material is usually the same almost fluid marsh material as that of the foundation (Nichols 1959). Nichols noted that "When water is over the marsh the surface material is supersaturated and becomes very weak and almost fluid. Poorly shaped levees which spread across the marsh result from this condition."

With the deposition of spoil along canal edges during dredging, especially in areas of heavy dredging with several crisscrossing canals, spoil banks may form a small lake or bay called an impoundment (Monte, unpublished MS). The formation of an impounded area disrupts the marsh system causing a change in the morphology of the coastal system. As the marsh areas are important both as nursery grounds for many sport and commercial fishes and for nutrient regeneration and production of organic matter, their destruction means a loss of productivity. The high productivity levels that existed in these areas previous to impoundment are difficult to maintain without the normal water level fluctuations and the resultant circulation energies (Copeland 1974).

In the past, levees were characteristically continuous. More recently, the Louisiana Wildlife and Fisheries Commission (LWFC) has required openings to be cut in levees in order to minimize disturbances to existing drainage and use patterns (LWFC 1972).

On state and some privately owned property a system of weirs has been employed to reduce the damage of pipeline canals. These water control structures are placed on the man-made channel wherever it crosses a natural waterway.

Weirs are structures placed in marsh tidal channels to stabilize water levels by controlling the exchange of flow between canals and natural waterways. They are constructed of wood, steel, or other material and are usually set about six inches below average marsh ground elevation. When water level is above crest level, water can be exchanged between the marsh and the channels (Burleigh 1966).

Heavy equipment is required for weir construction. Steel or creosoted lumber sheet pilings are driven at least two feet into the ground for every foot of water depth. The edge of the wooden structures are covered with shell to prevent damage by fire (Yaviz 1967).

Draglines are used to bring in material and drive pilings. Steel is used in the large or deep channels as it is easier to install and is not affected by fire or marine wood borers. All wooden material is treated with creosote.

Wier sites are carefully selected in a straight reach with well defined banks. Water depths should not exceed six feet. The weir crest is determined by reference to marsh level.

Water is drained from the affected area, for if the weir is too high, the water will be forced around the ends of the structure, thus forming a new channel. Weirs often have splash boards to prevent water from eroding and deepening the bottom when it spills over the weir (Chabreck and Hoffpauir 1965).

When the two stages of pipeline canal construction are complete, hydrocarbons may be distributed through pipelines to refineries, processing plants, or storage areas.

Plants, storage areas, support offices

The construction of refineries, processing plants, and storage areas onshore requires the use of architects, contractors, construction, crews, engineers, laborers, maintenance personnel, and all the related services from churches to laundries to support the work force and the associated families. Appendix C is a list of services associated with OCS oil and gas development.

Storage facilities require the construction of tanks in an area which is impounded by levees so that in case of a spill there is no leakage into the surrounding environment. Dikes must be high enough to contain all the oil that is stored.

Gas processing plants, petroleum refineries, and such facilities require large-scale operations. Most plants, therefore, are built to at least the minimum economic size; the size which will be assured to be operated at maximum capacity.

CHAPTER 2

NAVIGATION ACTIVITIES ASSOCIATED WITH OCS DEVELOPMENT

In OCS oil and gas development activities, the transportation of men and supplies from shore to the drilling or production sites is most often done by boat. And there are numerous subcontracted services associated with drilling and production that also require the transportation of men as well as goods and services to the offshore facility sites.

Boat rental and towing companies require onshore facilities such as ports with adequate docks, navigation canals, and offices. Additionally, there is the necessity of shipyards for boat building and boat repair.

Ports

Port facilities are necessary for the loading and unloading of men and supplies. At the port there are docks which may be referred to as wharves, bulkheads, or piers.

Piers or jetties project into the water. A pier can be used for docking boats on both sides. Wharves parallel the shore, and have only one side for docking. A bulkhead leans against the shore and is often used to support the ground behind; it, too, is only for one-side docking.

In choosing the type of dock to be constructed, factors such as the function of the dock, the size of ships, the direction of wind and waves, soil conditions, and economics are considered. Oil docks are generally of light construction, since the product is usually unloaded at fixed points and transported by pipeline. Heavier docks with warehouse facilities may be used for other services--such as equipment transport and food and laundry service.

There are two general classes of docks: (1) open construction and (2) closed construction. Open docks can be further divided into a) high-level docks and b) relieving-type platforms. A high level dock has a solid deck slab (for oil piers it is of skeletal construction). The relieving-type platform has a main slab below the finished deck with the space between filled to add stability. The open type dock is either creosoted wood, reinforced concrete, or a combination of concrete and steel or wood. Piles are situated in transverse rows and are capped by girders. Longitudinal beams are put at strategic points where the load will be concentrated. The various combinations of piles and deck are shown in Figure 8.

Closed construction utilizes steel sheet piles where the depth is fifty feet or less and the bottom conditions are suitable. The piles are topped with a concrete slab of bulkhead wall. The inside is filled to form a gravity wall to resist overturning at the base. Sheet pile bulkheads may be constructed of wood, steel, or concrete. Supporting tie rods are attached to an anchor wall situated in back of the face of the bulkhead. In shallow water this support may not be necessary. This type of dock is used as a service dock for oil rigs (Quinn 1967).

Navigation Canals

Navigation canals are dredged periodically to increase depth. Both the bucket dredge and the hydraulic dredge are used in channel maintenance.

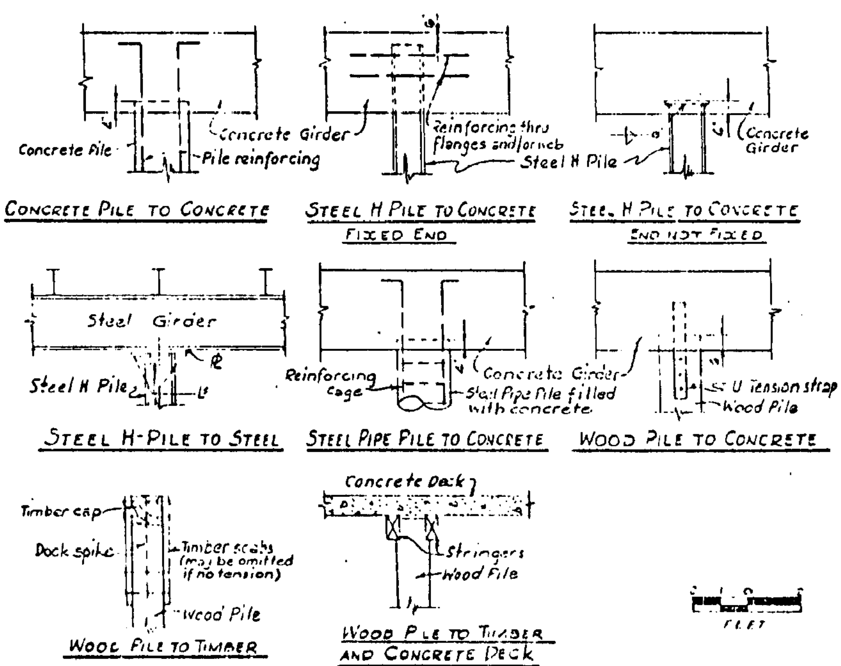


Fig. 8. Typical connections of piles to superstructures. (Quinn 1972)

In the Mississippi Delta region, however, siltation patterns are often unpredictable. For example, a canal that once was cleaned out twice a year may not be redredged for two years because of a shift in sediment supply. On the other hand, another canal may suddenly begin silting up quickly. As much as 50 percent of some dredging firms' business is involved in channel maintenance (Davis 1973).

Should a new canal be needed, oil companies will contract for an eight foot channel but will pay for a two foot "overdepth" to reduce maintenance. It is more economical for the oil companies to excavate a larger channel than required rather than rent a dredge to maintain channels (Davis 1973).

Water-control structures such as weirs and locks are associated with navigation canals.

A navigation lock is another form of water control structure (weirs were discussed with pipeline canals). The lock is a chamber with open ends that is used to transfer vessels between channels or pools of different elevation. The end opened to the channel is closed by gates. The vessel is admitted to the lock chamber, the entrance gate is closed, and the water level is equalized with that of the next pool. The exit gate can then be opened to allow the vessel to proceed on its way. Locks are located in straight parts of the channel to keep approaches clear (Schoklitsch 1937).

Lock walls and floors are constructed of concrete. Typical walls are shown in Figure 9 (Matthes and Stratton 1956). Lock walls must be constructed to withstand the pressure from both the water in the chamber

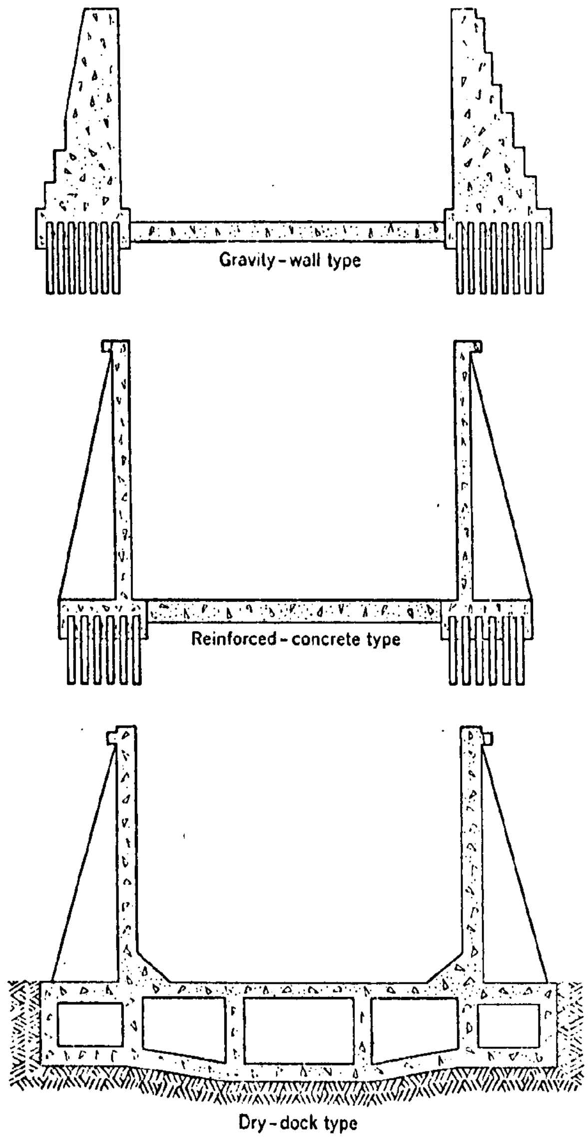


Fig. 9. Typical navigation lock sections.
(Mathes and Stratton 1956)

and the earth beneath and next to the walls. Walls and floors can be constructed in various ways. A monolithic construction forms a U-shape structure resting on soil. The walls can be set either on a continuous slab floor or beside the floor and can be made of sheet piling. The inner faces of the walls are made vertical. Battered or earth bank walls can be used as water economics permit. The floors of locks are below groundwater table. The construction pit is emptied of water by pumping.

The upper and lower heads of a lock close off the chamber from the adjoining pools. The gates are placed in the lock heads, which resemble movable water-tight weirs. Bay floors and bay walls bind the lock heads. The floor has a gate sill at the lower end for the lock gate seal to press against when the gate is closed.

The facilities for filling and emptying the lock chamber are placed in the lock heads. The simplest device consists of valves placed at the gates. Other methods, such as short longitudinal culverts and quoin culverts, have been devised but are very expensive.

Shipyards

Shipyards support OCS-related navigation with boat construction repair centers. The yards must be built along navigable waterways, which sometimes must be dredged to allow larger boats or rigs to pass to the Gulf of Mexico. The size of the boats under construction, or in the case of OCS-related activity, the size of mobile rig under construction determine the amount of dredging.

The size of the shipyard and its drydock facilities for repair and service of boats vary from small operations where only one boat at the time may be built, to large operations where dozens of craft may be constructed simultaneously. But construction of the shipyard, just as the construction of aforementioned plants and oil-storage areas, requires detailed planning, surveying, and excavation of the area.

CHAPTER 3

LAND-BASED TRANSPORTATION ACTIVITIES ASSOCIATED WITH OCS DEVELOPMENT

Services to offshore drilling operations require transportation facilities onshore. Along with navigation canals and shipyards, roads, railroads, and airport services are land-based necessities. Two related problems, landfill and drainage, are also dealt with in this chapter.

Highway Siting and Construction

Once it has been established that a road or highway is needed in a certain area, a two-stage reconnaissance is carried out. The first stage determines whether the proposed project is feasible; the second stage determines the best route for the preliminary study.

A reconnaissance survey of the terrain must be made. Boundaries of the major soil deposits are determined by field inspection and a study of aerial photographs and agricultural soil maps. From past experiences in highway construction and a general knowledge of the engineering properties of different soil types, a summary of highway design considerations is made.

The fundamental requirements of highway design are (1) to provide a method of constructing an embankment that will be stable against lateral movement during and after construction, and (2) to eliminate all post construction differential settlement of the foundation that would be detrimental to pavement performance or to driver safety (Root 1958).

The preliminary soils investigation and design phase of the

Table 2. Louisiana Department of Highways minimum design standards for rural highways and roads.

ITEM NO.	ITEMS		A SYSTEM	B SYSTEM	C SYSTEM			LOCAL ROADS	
		CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5	CLASS 6	HARD SURFACED	AGGREGATE OR NO SURFACE
1	Current Average Daily Traffic	Over 12,000	12,000-3,001	3,000 or less	1,500-751	750 or less	400 or less	300 or less	100 or less
2	Number of Traffic Lanes	6	4	2	2	2	2	2	2
3	Width of Each Lane	12'	12'	12'	12'	11'	10'	9'	9'
4	Width of Shoulders Minimum Desirable	10' out. Ins. 6'	10' out. Ins. 6'	8' 10'	8'	6'	6'	3'	3'
5	Width of Median	44' depressed 20' other	44' depressed 20' other						
6	Right of Way Width	300'	300'	150'	120'	100'	80'		
7	Minimum Width of Bridges (Measured from Face to Face of Bridge Rail)	98'	74'	32'	32'	30'	28'	20'	20'

exploration stage are usually confined to soil deposits where major embankment foundation problems are expected. Subsurface explorations and testing are required to develop the soil profile and the strength and compressibility characteristics of each soil stratum. From this information the engineer is able to determine the general type of treatment required and is also able to prepare a preliminary cost analysis. The selected solution may be influenced by nonsoil factors such as highway alignment, grade requirements, expected time of construction, right-of-way costs and limitations, land usage, available materials, and design class of highway.

Additional explorations, testing, and analyses are made to determine the details and limits of the foundation treatment. Sufficient drawings, special notes, and specifications are required for the contract documents. These documents are effective in giving the contractor and supervising engineer an understanding of the purpose, desired results, and methods of payment for the treatment (Moore 1966).

The selected method, or combination of methods, used in providing a stable foundation for highway embankments depends not only on soil properties, but upon an evaluation of all the other design factors previously mentioned (Moore 1966). The three main methods are: soil removal (by excavation or displacement); construction rate control (through use of berms, lightweight fill, and surcharge); and bridge construction.

To give the highway a stable foundation, soil is extracted where deposits are mainly organic. A typical peat or muck may contain, by volume, nine parts water and one part organic or inert soil. This material is highly compressible under embankment loads and is difficult to stabilize in order to obtain a smooth pavement for high-speed traffic (Moore 1966).

Sufficient explorations should be made to determine the depth of excavation and predetermine the amount of soil required for fill. The width of the excavation should be such that the side slopes will not be unstable resulting in lateral movement or settlement of the roadway shoulders (Moore 1966).

Disposal of excavated material may be a problem. Unsuitable surface soils can be disposed of hydraulically by either wasting over the surface of adjoining marshes or pumping into diked disposal areas. The resulting trench is filled with a suitable fill, preferably sand, which settles to a stable bed. The paved roadway is built upon this foundation. As an alternative, the solid spoil is removed with a clam shell dredge and piled alongside the right-of-way; this is called sidecasting (Fig. 10). With this method, the spoil is pulled back along the roadway after construction, forming part of the slope from the highway down to the marsh (Gosselink et al. 1972).

A special stabilization problem is encountered in widening projects on secondary roads crossing swamps. These old roads are usually floating on fills that have settled to considerable depth below the swamp surface. The existing roadway is reasonably stable since the underlying soil is well compacted after several years of loading. Any new embankment material placed on the adjacent swamp surface will undergo settlement of varying amounts, creating a differential settlement problem (Moore 1966).

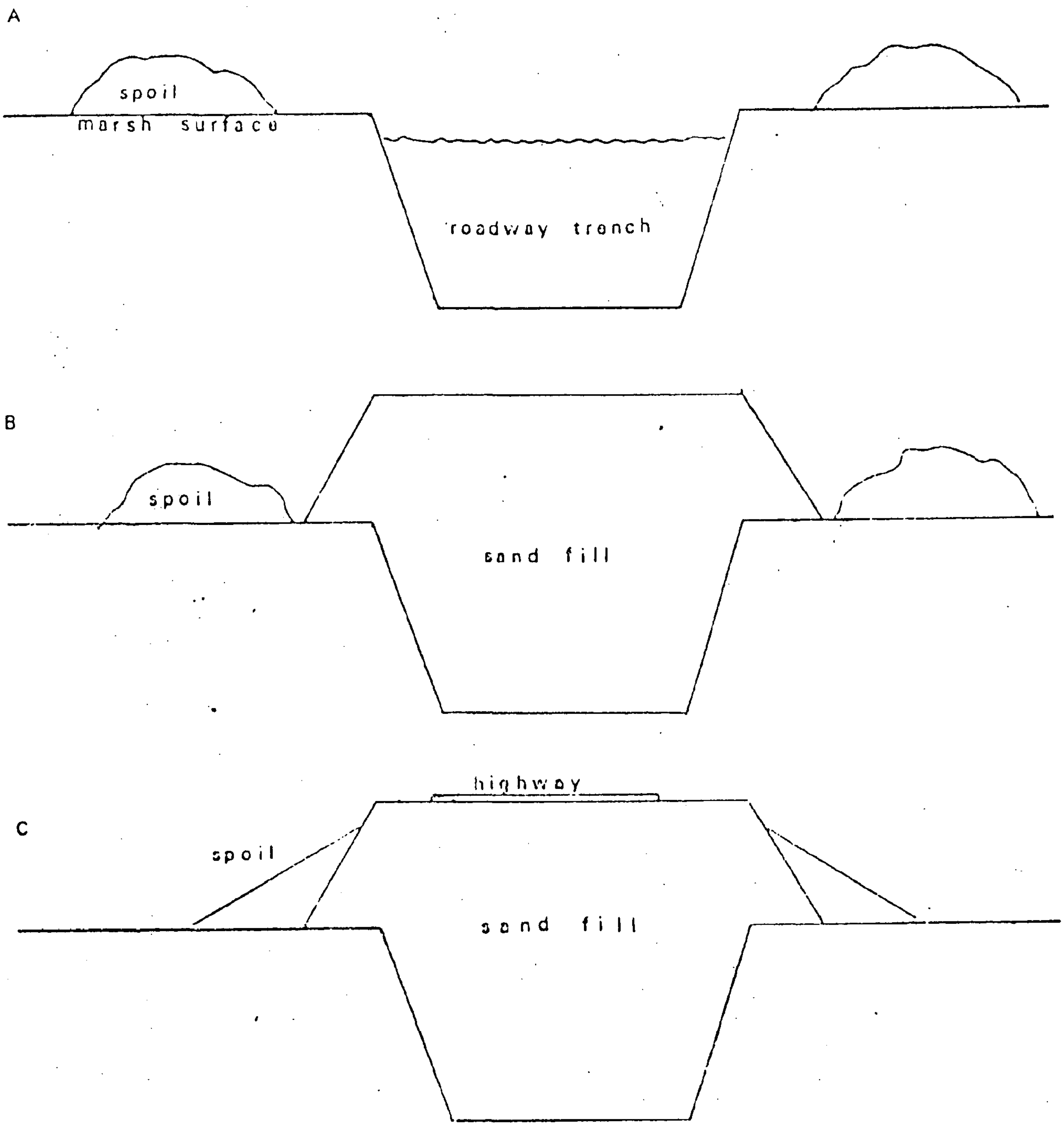


Fig. 10. Diagram of side-casting technique of spoil excavation. (Gosselink et al. 1972)

Another treatment method is to remove the soil by displacement. The displacement procedure is accomplished by placing sufficient embankment material on the foundation soil to cause the underlying soil to displace by shear failure in the direction of least resistance. The displacement method is used for peat and muck deposits greater than thirty feet in depth where complete excavation is difficult, and where the slope would collapse after the removal of very soft clays or organic silts (Moore 1966).

In a swamp with an irregular to firm bottom, difficulty is encountered obtaining complete displacement when the displaced soil is directed against a rising firm bottom surface. The front of the fill should be skewed as necessary to direct the displacement toward the deeper portion of the swamp (Moore 1966).

In deep swamps, culverts should be placed where the organic material is shallow, usually near the edge of the swamp (Moore 1966).

Occasionally, the organic material is underlaid by very soft clays that increase in strength with depth. In a situation like this, a detailed laboratory testing and stability analysis is required to predict accurately the depth of displacement needed (Moore 1966).

The surface root mat (left by plants) is removed at least thirty to forty feet ahead of the backfill to promote displacement. All excavated material is cast behind the advancing fill front or removed from the site (Moore 1966).

The two previous treatments involved the removal of foundation soil. The following methods involve treating the soil in place to provide a stable foundation. These methods are the most economical when they can be used since they involve no additional construction materials. The only requirement is to allow adequate time for the foundation soils to consolidate and gain shear strength. For construction projects extending over several years, stabilization periods of six to nine months may be used on portions of a project (Moore 1966).

When the weight of an embankment causes shear stresses greater than the shearing strength available in the foundation soil, a possibility exists that the embankment will cause the underlying soil to displace laterally. The zone along which this movement takes place approximates a circular arc with the center of the arc over the side slope of the embankment (Moore 1966).

The stability of various combinations of berm widths and heights are studied to determine the most economical and satisfactory solution. The toe of the berm should extend beyond the arc of the critical circle. Also, the berm should be checked for stability to ascertain that the berm itself will not fail. A series of step berms have been used to achieve stability of the berm embankment (Moore 1966).

Another solution to stability problems is to decrease the weight of the embankment by using a material of a lighter density than ordinary earth embankment material (Moore 1966). New highway construction techniques in the coastal Louisiana marshes call for clamshell road bases instead of fill. Although clamshell costs twice as much as conventional embankment materials on a per volume basis, it is a bargain in that it makes the job of building highways over soft material more manageable.

Only about 30 percent as much shell is used compared to the amount of conventional materials. Developed by the Louisiana Department of Highways for south Louisiana's marshland terrain, clamshell road bases are being used to relocate and enlarge a short section of U.S. 90 in Lafourche Parish. A three-foot deep layer of shell was found sufficient to support haul trucks (because shell is lighter than soil or sand, it virtually floats like a raft on the marsh muck). Experiments showed that the shell subsided only about two feet into the marsh under truck traffic. Instead of being shaken apart by the intense vibrations of a bulldozer, the shell was knotted very tightly together. An estimated $1.6 million will be saved on the 1-mile section of U.S. 90 while another proposed 4.5 mile section is expected to net a savings of $12.1 million (Morning Advocate 1975).

Embankments are often built to heights above future pavement grade to decrease the post-construction settlement. The effectiveness of this method, called surcharge, is dependent upon (a) time-settlement characteristics of the foundation soil, and (b) the ratio between surcharge height and final fill height. If the fill is high and the compressible layer is deep, then the surcharge will be relatively ineffective (Moore 1966).

The effect of a surcharge loading on the stability of the embankment should be checked. Often a surcharge may be desirable from the standpoint of settlement but would undermine the stability of the embankment by inducing shear failure (Moore 1966).

Surcharges have been used effectively in areas where bridge abutments are located on soils such as loose silts, fine sand, and clayey silts that consolidate rapidly. By preloading the abutment area, the structure settlement may be reduced to a magnitude that allows the use of spread footing foundation instead of piles. The economics of a surcharge treatment should be studied since payment is required both for placing the material and for removing it to subgrade elevation (Moore 1966).

An entirely different method of highway construction is to bridge the marsh. This disrupts the ecosystem the least, especially the water flow patterns, which are important in tidal marshes. Marsh loss is minimized since only enough marsh for an access canal and spoil bank are destroyed. The canal uses about one-half the width of the right-of-way (Gosselink et al. 1972).

Bridge building has been resisted because construction costs are four times the cost of a filled roadway (Georgia highway construction data). However, as marsh loss is minimized, the total cost of the different techniques is more nearly equivalent (Pope and Gosselink 1973).

From interviews with construction engineers and maintenance engineers of the Louisiana Department of Highways, Pope and Gosselink (1973) were able to compare the cost of a filled roadbed versus an elevated roadway/bridge (Table 3). Their data represents the average or normal costs for such construction, varying with locale and project.

Railroad Siting and Construction

Railroad siting is accomplished in the same manner as highway siting. First a broad reconnaissance of the general area is performed

Table 3. Estimated average costs of freeway construction across marshland in Louisiana.*

	Costs	
A. Filled Roadbed[2]	Assumption I 2.5 ft Removal	Assumption II 8.0 ft Removal
Removal of mud to diked area, $.56/yd[3]	$ 819.26	$ 2,621.63
Fill, from borrow pit, $1.85/yd[3]	5,700.74	13,539.26
Basecoat, $7.50/yd[3]	1,631.67	1,631.67
Topcoat, $10.50/ton	5,646.67	5,646.67
Total construction cost per 100 linear ft	$13,798.34	$ 23,439.23
Estimated destruction of marsh by roadbed and spoil	1.4508/acres/100 ft	3.8448 acres/100 ft
Annual maintenance cost	$19.23/100 ft	$19.23/100 ft

B. Elevated Roadway (Bridge)[3]	Costs
Concrete poured in place	$120,000
Pre-stressed sections	104,000
Estimated destruction of marsh by construction canal	.0918 acres/100 ft
Annual maintenance cost	none

Notes: *A. Filled roadbed under two assumptions about mud depth.
B. Elevated roadway. All figures represent cost per 100 linear feet of construction; all prices for materials in place[1] (from Pope and Gosselink, 1973).

[1]Source: Mr. Lawrence Doucet, Construction Engineer, and Mr. F. E. Crawford, Maintenance Engineer, Louisiana Highway Department.

[2]Specifications: Highway--fill to 1.5 ft above marsh level, two double lane roadways, each lane 12 ft, shoulders each 10 ft, median of 30 ft; total width of fill, 158 ft life expectancy 20 yrs.

[3]Specifications: Elevated roadway--two double lane bridges, each 40 ft wide, elevated 10 ft, costs computed at $15/ft^2 poured in place, $13/ft^2 poured pre-stress construction, life expectancy 30 years.

to determine all feasible routes. By studying maps and air photos, these routes are compared as to terrain, valley and ridge lines, water courses, approximate grades, service, convenience, and right-of-way and construction costs.

Next a preliminary survey of the general route is performed to obtain detailed information as to topography, drainage, soil conditions, river crossings, land use, and other areas. This helps to establish a final route and to estimate costs. The preliminary survey consists of a transit for locating property lines, buildings, roads, bench mark and profile levels, and location of contours. Ground profiles are plotted, tentative grades established, and earthwork quantities computed (Babcock and Bone 1959; Pryor 1956).

A location survey is done next (1) "to provide location stakes and grade information for the center line; (2) to provide base-line survey stations for cross sections and for setting slope stakes, structure stakes, and right-of-way stakes; and (3) to provide data for final design and computation of grading and other pay quantities" (Pryor 1956).

The location survey is carried out once the route has been established and the permission to use the right-of-way obtained. A single track line requires from a 66-foot to a 100-foot right-of-way. This figure increases with the addition of other structures and facilities. Areas for rights-of-way are given in Table 4 (Hay 1945). Future needs should be taken into consideration when planning the right-of-way.

Table 4. Area of right of way

Width ft	Acres per Mile	Acres per 100 Ft	Width ft	Acres per Mile	Acres per 100 Ft	Width ft	Acres per Mile	Acres per 100 Ft
16.5 1 rod	2.00	0.038	27	3.27	0.062	40	4.85	0.092
			28	3.39	0.064	41	4.97	0.094
17	2.06	0.039	29	3.52	0.067	41.25 2.5 rods	5.00	0.095
18	2.18	0.041	30	3.64	0.069			
19	2.30	0.044	31	3.76	0.071	42	5.09	0.096
20	2.42	0.046	32	3.88	0.073	43	5.21	0.099
21	2.55	0.048	33 2 rods	4.00	0.076	44	5.33	0.101
22	2.67	0.051				45	5.45	0.103
23	2.79	0.053	34	4.12	0.078	46	5.58	0.106
24	2.91	0.055	35	4.24	0.080	47	5.70	0.108
24.75 1.5 rods	3.00	0.057	36	4.36	0.083	48	5.82	0.110
			37	4.48	0.085	49	5.94	0.112
25	3.03	0.057	38	4.61	0.087	49.5 3 rods	6.00	0.114
26	3.15	0.060	39	4.73	0.090			

Note: For greater widths use sums or multiples; thus, for 87 ft take the sum of the acres for 43 and 44 ft.

Source: Hay, 1956.

Earthwork

The right-of-way is cleared of all trees, brush, and perishable material. Brush is burned or moved without injury to adjoining property. Stumps are cut close to the ground; those between slopes of embankment must be covered with at least 2.5 feet of fill. Stumps are grubbed from all places where there is excavation and between slopes of embankment less than 2.5 feet high (Crandal 1913).

Grading includes all excavation and embankments for the formation of the roadbed, ditching, diversions of roads and streams, foundation pits, and all similar work (American Railway Engineering Association 1921). A roadbed is excavated to subgrade level. The width of the subgrade depends upon the character and dimensions of the ballast and track (Babcock and Bone 1959). The roadbed is then filled to grade drainage, prevent upheaval by frost, and better distribute the load over the railroad (American Railway Engineering Association 1921). Ballast is then used to prepare the roadbed for the ties and track. The choice of material used for ballast depends on availability and expediency of existing circumstances. The choices are listed below in order of decreasing preference: stone, washed gravel, broken slag, screen gravel, pit run gravel, chats, burnt clay and cinders (American Railway Engineering Association 1921).

Soft underlying clay subgrades and muck or peat soils can cause instability. The soft material must be excavated and replaced with good soils. Settlement can be hastened by overloading the fill and shooting the muck from underneath by drilling blasting holes transverse to the overloaded subgrade. Pressure granting also helps to stabilize a roadbed. Granting entails forcing a "slurry" of cement and sand into the subgrade by use of pressure (Babcock and Bone 1959). Lowering the water table by using surface ditches and vertical sand drains beneath the fill aids in stabilizing the foundation. Timber mats may be used to give support; in severe cases trestles are used or the line is relocated. If slow subsidence is a problem, the track has to be raised to replenish ballast at appropriate intervals. Slides can be prevented by locating on trouble-free ground and on graded stable slopes that are adequately drained (Hay 1956).

Figure 11 depicts a typical crossection of a railroad embankment ballast section. The track is held in line by the ballast, which provides drainage and distributes the load uniformly. The amount of ballast used depends on the type and amount of traffic, the kind of ballast, roadbed conditons, and distance between ties.

Wooden ties, seven by eight inches and eight to nine feet long, are the standard. They are normally spaced at twenty-one and a half inch intervals. Usually they are made from oak, Douglas fir, and mixed hardwoods. Ties are treated with creosote and a creosote-coal tar mixture or a creosote-petroleum mixture. Treated ties have a service life of about 30 years.

Rails are made from open hearth steel with a standard length of thirty-nine feet. In order that they may act as continuous girders, rails are connected by joint bars made of carbon steel. Other materials used to assemble the rails are spikes, tie plates, rail anchors, and assemblies (nuts, bolts, and washers). Rails are fastened to the ties by hook-head spikes. Tie plates are used under the rails to help distribute the load and prevent bending of the plate. Rail anchors are used to hold the rail so it cannot move without the tie and ballast (Babcock and Bone 1959).

Drainage for railroads is very important. Surface drainage is provided by side ditches and intercepting ditches. Except in impervious soils (containing more than 20 percent clay) subdrainage may be obtained by use of pipe drains. There is no reliable method of draining impervious soils.

Bridge and causeway construction

The location survey done during highway and railroad surveying will provide enough information for use in design of small bridges. Long bridges require a special topographic survey of the site. Information on the character of the watershed and stream bed, elevation of the highest water, and character of the foundation should be available.

Short bridges (no offshore piers) require a center line of roading to be established by using a governing line. Also governing lines for each wing wall are established onshore. For long bridges transit stations are established onshore by triangulation.

Today piers and abutments for bridges are built mostly of reinforced concrete. Piers are designed as single circular columns, rectangular columns, or two or more columns on a common base with a common cap. Piers can also be formed of clusters of steel, precast concrete, or timber piles topped by a common cap and strengthened by stiffening diaphragms. Piers and abutments may have foundations on spread footings deep enough not to be affected by scouring or on piles (Mack and Proctor 1956).

Figure 12 shows the different types of bridge spans. A simple span is a single one free at either end with one support permitting horizontal rotation. A cantilever is a combination of simple spans with overhangs. A continuous structure is a simple span with additional supports. An arch is a curved beam with supports. A suspension structure is essentially a roadway hung from cables supported by towers and anchored at the end. These types may be combined in different ways. Spans may be fixed or movable depending on whether they cross navigable waterways.

Floors of bridges for railroads may be either open deck or ballasted. The open deck floor consists of the track and guard rails fastened directly to timber crossties, the spacing between the ties being open. A ballasted deck structure has the track encased in ballast with the track and ballast being supported in a shallow trough.

Highway floors are concrete or steel, with timber seldom used anymore. Reinforced concrete is the most common type floor for a fired steel span. Concrete slabs are fixed either on longitudinal beams or transverse beams. Steel floors are frequently used in movable spans because of their comparative light weight. Grating floors and plate floors are the two general types. Grating floors are either open or filled with concrete. The gratings are parallel main bars spanned between supporting beams. Plate floors span transversely between longitudinal beams; they may be used with or without pavement (Granger 1956).

Navigation requires some bridges to be movable. There are three types of movable bridges: (1) swing, (2) vertical lift, and (3) bascule spans. Swing spans rotate on a horizontal plane around a center pier;

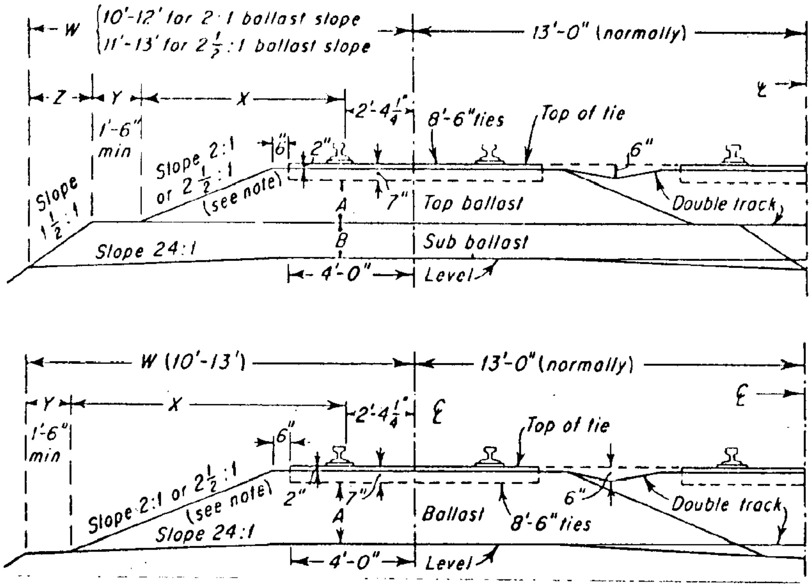


Fig. 11. AREA ballast sections for tangent track. (AREA 1921)

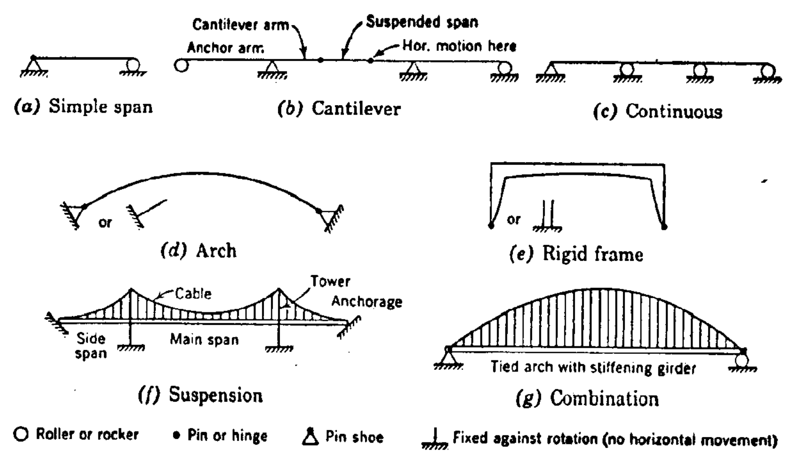


Fig. 12. Types of Bridge spans (Grange 1956).

lift spans move vertically like an elevator; and bascule spans rotate in a vertical plane.

Airport Siting and Construction

Selection of an airport site depends upon the area required, possibility for expansion, accessibility to the community, absence of obstruction in approaches, freedom from fog and smoke, nature of the terrain, proximity of other airports, and cost of development. The area needed depends upon the type of airport, runway length, and terminal requirements. A small personal airport may need 50 to 150 acres (Babcock and Bone 1959). The terrain should be flat; elevated sites are preferable to lowlands. Obstacles such as mountains, hills, tall buildings, transmission lines, chimneys, and towers should not be in the approach areas.

Surveying for airport sites consists of checking USGS topographic maps and aerial photographs to study relief. Soil maps are used for foundation and drainage studies. Possible sites are investigated in the field, and detailed studies are made of the most desirable site.

Surveys should be made of soil components on the site chosen. The site should be clear, easily drained ground with a sand or gravel soil type (Babcock and Bone 1959).

Orientation of runways should be such that the aircraft may land 95 percent of the time with less than 15 mph cross winds. Traffic volume will determine the number of runways required. One runway properly oriented may give adequate wind coverage. More than one runway is justified only to meet traffic requirements (Moore 1956).

Determining the site of an airport depends upon the soil profile. In cases where the only available site is in a low wet area that will not support the necessary fill material, special precautions and measures have to be taken. A subsurface investigation must be carried out determining the depth, moisture content, density, permeability, and shear and consolidation characteristics of the soft material (Moore 1956).

The same methods of excavation and construction are used in both highway and railway projects. Aeronautical considerations may call for special variations in gradients, slope, or compaction methods.

If the landing strip is located in a cut, the area should be wide enough to have the necessary drainage ditches at the edges of the strip. The edge of graded areas should be smooth so that no abrupt drop exists between the landing strip and the marsh. Grading work should be closely coordinated with drainage requirements.

Embankments are to be compacted to not less than 90 percent of maximum density at optimum moisture. This is increased to 95 percent for the upper nine inches in fill and upper six inches in cuts under all paved areas.

Drainage is necessary to reduce the amount of water going into the soil and to maintain a firm, stable, dry surface. The drainage system should provide for the interception and removal of surface and underground water from the airport and surrounding area.

Cut and fill slopes are made as flat as possible in airport construction. Slopes are often planted with fast-growing vegetation to help prevent erosion.

Pavement can be either rigid or flexible. Rigid pavement is made of concrete. Flexible pavement consists of a bituminous wearing surface resting on a nonrigid base with a subbase course where required (Moore 1966). Smaller airports usually have bituminous surface; larger classes have a plant mix bituminous concrete. Concrete pavement is commonly used for aprons since it is unaffected by fuel, oil drippings, or shear stress and is less affected by jet blast (Babcock and Bone 1959).

Heliports require touchdown pads that should be a minimum of twice the diameter of the rotor. The safety area should extend a minimum of fifty feet from the outer edge. Sea plane facilities require a complete survey of the water area--bordering shore line; terrain; land development, length, width, and depth of the water operating area; current velocity and water level differential; shoreline and bottom characteristics; prevailing winds and velocities; sheltered areas and mooring areas; approach conditions and obstructions; and local boating. Nearby property owners and onshore activities have to be considered. Location of floats, docks, ramps, tiedown aprons, hangars, and other buildings must be taken into account (Babcock and Bone 1959).

For all types of airport terminals, facilities are determined by the size and purpose of the field. Location of other transportation facilities and public utilities must be taken into account when locating the airfield.

Landfill and muck disposal

Landfill techniques and mud disposal are important in highway, railroad, and airport construction. Modern landfill and embankment techniques are aimed at stabilizing both the soil that will support the earthwork and the fill. Early completion of consolidation and settlement is advocated. It is impossible to stabilize compressible materials like organic silts and peat. These soils are excavated and replaced by a compacted stable soil such as sand or sand and gravel mixed. Two other methods of filling that have been generally unsuccessful are (1) to place new fill in the area and squeeze out the soft material; and (2) to put new fill over the soft material and suction the soft material out through holes in the new fill. Excavating the soft material and bringing in new fill is considered the most reliable method.

Figures 13 (a and b) show the soft material being excavated by (a) dragline and (b) hydraulic dredge. Of the two dredges, the hydraulic dredge is preferred as it removes deep deposits more readily. It is more reliable than the bucket dredge as the latter may leave pockets of soft material that consolidates and causes settlements later (Fig. 13c). The displacement method (Fig. 13d) is used where excavation equipment cannot be brought to the site. A dragline excavates to the maximum feasible depth. The fill is dumped to a height above finished grade and consolidated by promoting outward sliding and displacement of the soft material. This causes mud waves, which are excavated ahead of the fill. This method often leads to uneven settlements.

Blasting is also used to displace soft material both ahead of new fill and under partially completed embankments. There are two methods used. The first (Fig. 14) known as toe shooting, involves charges put in the soft material ahead of an advancing fill. The soft material is blown out and liquefaction is promoted. This facilitates displacement

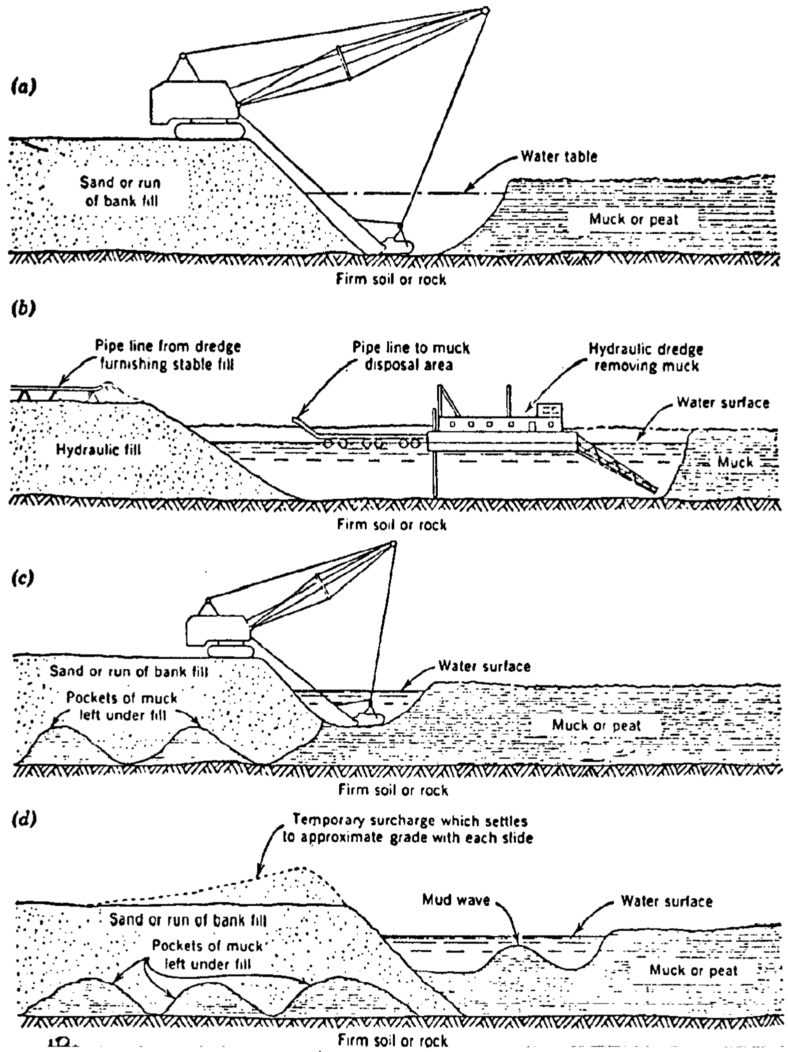


Fig. 13. Embankments in muck or peat. (a) Soft soil being removed by a dragline working from the end of the embankment built of stable material deposited by trucks. (b) Both excavation and fill being made by hydraulic dredges, a method that has proved economical on large projects. (c) and (d)Where excavating equipment capable of removing the full depth of soft soil is not available, this method is sometimes attempted (Mack and Proctor 1956).

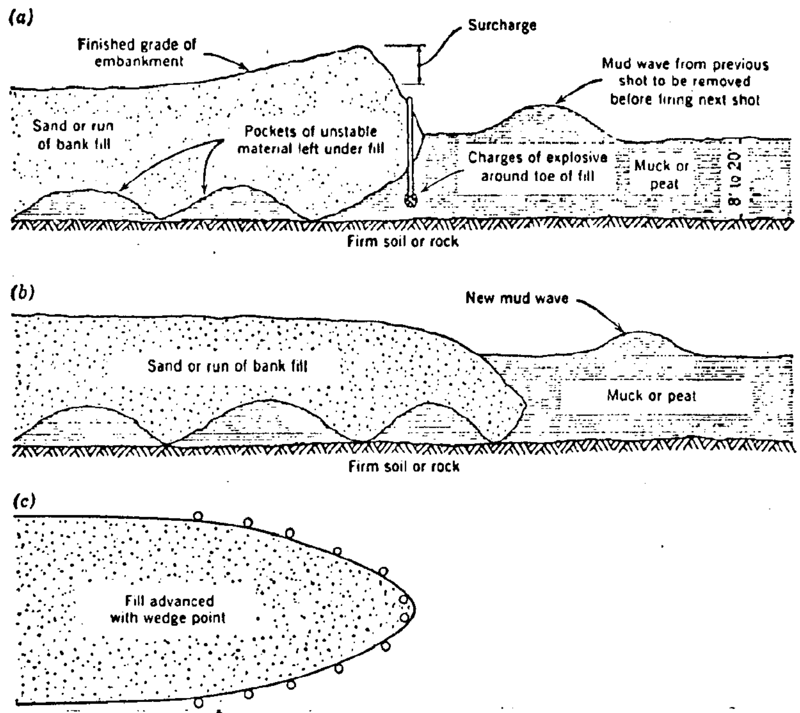


Fig. 14. Displacement of soft soil by toe shooting. (a) Explosives and earth surcharge before shooting. (b) Result of shot. (c) Plan showing arrangement of charges (Mack and Proctor 1956).

by heavier material. Toe shooting can be used only where the soft material is less than twenty feet thick. The second method, under-fill shooting, may be used where the soft material is thicker. Each blast can blow out fifteen feet of soft material from under the new fill. Blasting methods are unreliable and should be used only when it is impossible to use other methods. Where blasting is used, only flexible type pavements should be put on embankments constructed on marsh land. Fills are usually compacted by rolling with pneumatic rollers, by watering, or by shock loading.

Coarse sand and sand and gravel with no fine material are used for fill. The material is dumped and spread by bulldozers into eight-inch thick layers. Each layer is then rolled by a pneumatic tired roller hauled by a crawler tractor. Fine sands and silty soils can be compacted in the same way provided that the moisture content is controlled. Vibration compaction is effective for a low percentage of soils containing fine and cohesive particles. Vibrators are self-propelled power rollers fitted with a variable frequency vibrator. The most effective method to compact cohesive and partially cohesive soils is by rolling with a sheep's foot roller at a moisture content of 2 to 2 1/2 percent of the optimum (Mack and Procter 1956).

In modern landfill methods the excavated material (muck) is treated as dredged spoil. Dredged spoil is discharged either into waiting hoppers where it is carted to oceanic dumping grounds, to special impoundment areas, or to adjacent deep water.

Spoils are generally disposed of in open coastal waters not more than three or four miles from the dredging site. They account for 80 percent of ocean waste disposal by volume. The disposal sites off the Gulf of Mexico are depicted in Figure 15. Dredged spoils have been disposed of in the Gulf since 1926. All of the dumping is performed by hopper dredges. Volumes vary with year (Reed 1975).

The spoil may be carted to special areas impounded by levees. There the water is allowed to run off, leaving the solid material behind.

If the spoil is discharged into adjacent deep water, it must be discharged evenly along the bottom so that it does not create a shallowing effect.

Drainage

For railways, culverts and bridges provide openings to carry the normal flood flows of natural waterways without ponding. Tracks should be built high enough to avoid being washed out by floods. Drainage for roadways consists of artificial surface and subsurface cuts and fills in the roadbed. Lines should not be located by (1) cuts in wet springy ground, (2) long cuts on low gradients, and (3) fills across swampy ground which cannot be readily drained. Surface drainage consists of side ditches in cuts and intercepting ditches. Side ditches are at least one foot wide and one foot deeper than subgrade; slide slope angles depend on the material. A minimum gradient of 0.3 percent is necessary. Intercepting ditches are used on the upper side of cuts when the ground slopes toward the roadbed fifteen feet from the toes of fills that were superimposed on potentially unstable soils. Pipe drains, which may be used for subdrainage of wet cuts and saturated soils except for impervious soils, should be parallel to and nine feet from the line of the adjacent track on one or both sides. They should be 10 feet from the toe of the slope of embankments and have a gradient of at least 0.2 percent. Lateral pipes installed under the track may be necessary in wet cuts. Common subsurface drainage pipes are nitrified-clay sewer pipe with bell ends or perforated corrugated galvanized iron pipes. There is no remedy for drainage of impervious soils (more than 20 percent clay).

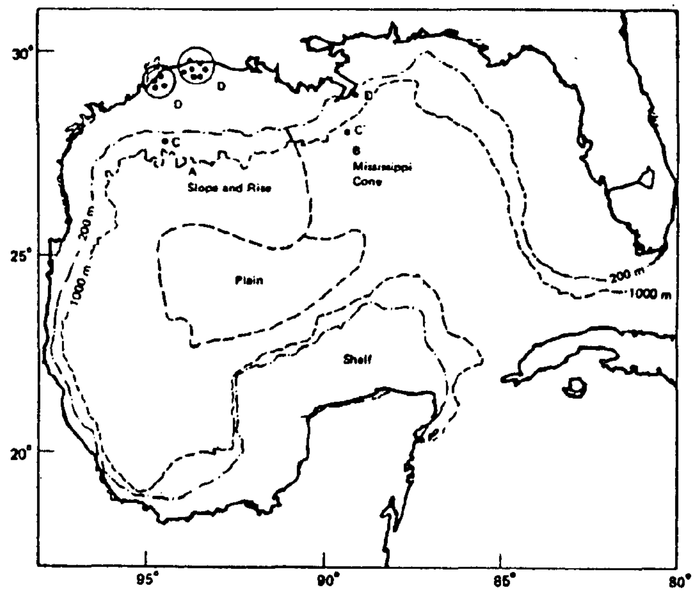
Good surface and subsurface drainage is necessary for a stable subgrade for highways. Surface drainage is acquired by topping the roadway and sloping the shoulder to side ditches or gutters. Runoff from nearby lands also gathers in these ditches. Ditches are placed at the top of slopes to gather surface flow and to prevent erosion in high cuts. The ditches lead to natural water courses or paved channels. Berms are built along the edge of fills to keep surface flow on top except where there are paved channels. Culverts are used for cross drainage at low points in ground profiles. Shallow ditch sections are used along important roads. Erosion is reduced by rounding tops of slopes and ditch sections. In populated areas, paved gutters on the outer edge of the pavement drain into catch basins leading to a storm sewer system.

Where subsurface drainage is needed, intercepting drains are built under the shoulders to lower the ground water level and to keep the subgrade moisture free. Water level should be four to six feet under the surface to reduce the rise of moisture by capillary action. Trenches filled with porous material serve as side drains. Clay pipe with open joints or perforated corrugated metal pipe is used at the bottom of the trench to collect the flow. The trench is sealed with impervious soil to keep surface water out of the drain. Typical facilities for drainage are shown in Figure 16. Soils that hold water by capillary action and areas that are low and swampy where outlet for side drains cannot be found require at least a layer of porous material under the pavement. Bleeder drains, which are porous outlets, can be provided at low points to prevent ponding in the base. There are some roads that are of natural earth and are not paved. Because both the nature of the soil and the effective use of drainage, these roads will be muddy during rains and have ruts at other times.

For surface drainage at airports, shallow ditches leading into storm sewer inlets are dug along the edges of landing strips. The inlets are either just outside the edges of runways or in depressions on the center edge of the pavement.

Subsurface drainage is achieved through the use of interceptor drains and pervious base course layers. Where there are paved runways, subdrains are built along the edges of runways as needed. The drainage system is designed around the layout of the runways, taxiways, aprons, and the terminal site plans (Babcock and Bone 1959).

Reclamation of marsh lands requires the impoundment of the area by levees or dikes and a good drainage system. It is sometimes necessary to use pumps when the water outside the impounded area persists for a long time.



D = Dredge Spoil C = Chemical Wastes

Fig. 15. EPA interim-approved disposal sites Gulf of Mexico (Reed 1975).

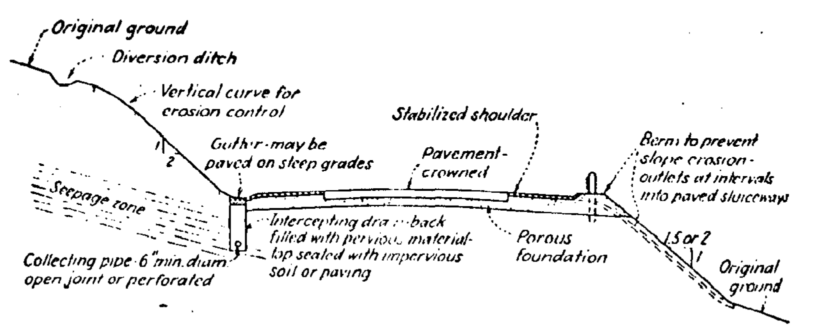


Fig. 16. Drainage facilities on side-hill location. (Barnes 1956).

CHAPTER 4

ENVIRONMENTAL IMPACTS RELATED TO OSC ACTIVITIES

Hydrocarbon Discharge

Hydrocarbon discharges, such as oil spills, are not an uncommon occurrence in Louisiana. Discharges can occur from drilling and production platforms, from pipelines, and from production structures. In addition, discharges can occur during transportation via tank vessels as a result of rupture of oil compartments and bilge disposal. On land, hydrocarbon pollution may result from highway, railroad, bridge, and airport construction.

There are at least five causes of oil spills from offshore platforms. Between 1964 and 1972 there was one blowout, two fires, two storms, two hurricanes, and one collision (MIT 1974). Regardless of the cause, the effects of oil in the water are basically the same. For this reason specific examples will be used to illustrate some of the impacts.

On December 1, 1970, oil platform ST26 "B" operated by Shell Oil Co. caught fire. The fire burned out of control and the heat produced resulted in the weakening of well piping and the subsequent escape of crude oil into the Gulf of Mexico. The platform was located seven miles south of Timbalier Bay. The site is contained in the Terrebonne Basin Management Unit. The estimates of the amount of spillage varied from 25,000 barrels by Shell to 53,000 barrels estimated by the USGS to a high estimate of 119,000 barrels estimated by the EPA. It is impossible to estimate exact amounts of oil lost in a spill such as this.

The oil was present on and in the water until April 16, 1971. Several effects of the pollution were monitored by Shell employees and other concerned agencies. The slick advance was primarily affected by surface wind vectors and near surface currents (reviewed by Stone 1972). The oil reached the beach just northwest of Bay Champagne near Grand Isle, La.

Biological sampling during the spill indicated that benthos and fish populations had been stressed by the presence of petroleum hydrocarbons in the water. There was a slight negative correlation between hydrocarbons in the water. There was a slight negative correlation between hydrocarbons and low epifaunal and infaunal abundance (reviewed by Stone 1972). As one approached the source of the oil (the platform), the epifauna and infauna decreased in numbers. Within two miles of the source, epifaunal and infaunal populations were at a density of 13,000 organisms per square meter. Beyond a two-mile radius the population density reached 48,000 per square meter.

The most apparent effect of the spill was on selected crustaceans. No adult stomatopods (mantis shrimp) were found within four miles of the shell platform. This may be an indication of pollution stress.

Fish were collected in the vicinity of the Shell spill and limited histological examinations on gill filaments of six fish species were performed. The results showed that gill filaments were swollen and epithelial cells were being sloughed off. This was presumably as a result of exposure to oil (Stone 1972). Fish populations were probably less affected by oil than benthic organisms because of their greater motility.

Meyers (1971) studied the succession of yeast species during the spill and compared their populations to those of oil-free waters. The predominant species complex was Rhodotorula/Rhodosporidium in clean water. Shortly after the spill, the Rhodotorula/Rhodosporidium complex bloomed to more than 200 cells/100 ml as opposed to 0-10 cells/100 ml in clean water. After thirteen weeks, however, this complex was absent while other species returned to normal levels. Meyers concluded that oil-decomposing types disappeared despite increased oil deposits because of a lack of nutrients (probably nitrogen and phosphorus).

Although, some information concerning the Shell spill is available, sources are infrequent and most monitoring is sketchy. Nevertheless, this spill offers some basic idea of possible effects of offshore hydrocarbon discharge.

Lund (1957) studied the effect on oysters' ability to clear suspended material from the water they pump through their systems. He reported no apparent effect on ability to clear water when exposed to crude oil.

Mills and Culley (1971) found that crude oil having having high gas content such as type Q-4-D is most toxic to shrimp. Concentrations of Q-4-D from 7.5 ppt to 75 ppt were fatal. They found also that the crude oil dispersants used in cleanups are more toxic to shrimp than the crude oil itself. Mixtures of oil and emulsifiers were more toxic than either individual component. The type of crude oil emitted from the Shell platform is not known at this writing.

Experiments by Kniefer and Culley (1975) showed that crude oil affects the taste of shrimp and crab meat. The type of crude oil was related to the degree of affected flavor. Oils with high light fractions (i.e., diesel, kerosene, gas) are more toxic and affect flavor more. One of these, Q-4-D, was detected in shrimp meat after exposure to 5 ppm.

Stone (1972) states that most significant effect of oil spills in Louisiana would be the damage to marsh grasses. These grasses provide organic material to both the marsh and offshore areas and loss of these marsh plants could affect populations of marsh-dependent species such as marine fisheries. Concentrations of 539 U.S. gallons per acre resulted in 50 percent die-off of experimental plants, and a higher concentration of 1,078 U.S. gallons per acre caused a 90 percent die-off after one year (Zobell and Prokop 1962).

Another study (Crow et al. 1976) dealt with the effect of Arabian crude oil on Spartina alterniflora in Louisiana. This grass is one of the dominant species in Louisiana saline marshes. The results showed that Spartina exposed to burning, cutting, or natural dieback was more susceptible to oil damage than intact plants. Furthermore, concentrations of less than 250 ml/m^2 caused no noticeable effect on whole plants while, in a clipped plot, regeneration was reduced by 70 percent. In all cases where plants were treated with oil, the overall plant mean height was less than in controls. Oil weathered for seven days had less deleterious effect on plants than fresh oil.

Pipeline discharges also affect the coastal environment. It is estimated that 96 percent of all pipeline spillage is because of ruptures, leaks, or structural failures. Bryant (Stone 1976) predicts superport pipeline spillage to be as high as seven gallons per pipeline mile per year.

Navigation

It is not possible at this time to accurately measure the amount of hydrocarbon spillage from ships in Lafourche Parish primarily because the data were not available to us. The statistical probability (based on Coast Guard data) indicates an average total expected spillage of seven tons per year off Lafourche Parish due to the superport project. Most of this spillage is expected to occur from collision.

Transportation on land

Onshore transportation-related discharges would most likely occur either at terminals or on pipelines. The average spill amount at a proposed superport terminal within Lafourche Parish calculated from Coast Guard Data is 6.1 barrels and that from pipelines is 5.26 barrels (U.S. Dept. of Transportation). Naturally, the amount of spill depends on the severity of the accident and the discharged commodity. Little concrete data are available in a compiled form and thus the transportation-related effects of hydrocarbon discharge are not quantitatively presented here.

Altered Drainage Patterns

Construction and maintenance of dredged canals can result in several adverse effects to the surrounding wetlands. Presence of canals interrupts the natural flow of water in the wetlands by altering existing circulation patterns. Under normal conditions, flushing of the marsh by water level fluctuations from tides and river high water keeps the marsh productive. The plants are submerged by high water allowing for deposition of suspended nutrients as well as dilution and removal of organic waste products. Channelization results in rapid drainage and interference with tidal submersion causing removal of nutrients from the marsh. In addition, canals allow further saltwater penetration into freshwater environments (Eleuterius 1971; Copeland and Dickens 1974). Specific references to individual canals can serve to illustrate the impact of canals on the coastal environment.

A numerical model of water flow over a small piece of Spartina marsh (500 ft by 1000 ft) has been developed by McHugh (in press). The effects of various restrictive devices were simulated: for example, a spoil bank barrier transversing the long axis, then the short axis, or put all around three sides of the marsh. Table 5 gives the results of these tests. A vertical barrier reduces water flow by 8 percent. A horizontal barrier reduces water flow by 22 percent. A surrounding barrier on three sides reduces water flow by 74 percent of normal circulation.

The Gulf Intracoastal Waterway (GIWW) transects all of coastal Louisiana in an east-west direction. The GIWW is maintained at 12 feet deep by 125 feet wide and is considered a shallow-draft canal (Vick 1975). The Army Corps of Engineers (1975a) reports that between 1945 and 1974 approximately 512 acres per year were required for maintenance spoil disposal. It is estimated that in the next 50 years 900 more acres will be required; the amount in Lafourche Parish needs to be estimated.

The GIWW acts against the hydrologic flow of nearly every major drainage basin in coastal Louisiana. This may result in the rerouting of runoff and of normal circulation patterns as well and may increase

Table 5. Relative changes in terms of percentage of water flow over a *Spartina* marsh.*

CONDITION	PERCENTAGE OF NORMAL
Normal Circulation	100
Vertical Barrier	92
Vertical Barrier (with breaks)	96
Horizontal Barrier	78
Horizontal Barrier (with breaks)	90
Vertical Barrier (80% into marsh)	46
Horizontal Barrier (80% into marsh)	42**
Surrounding Barrier (3 sides)	26
Surrounding Barrier (3 sides with Vertical Barrier)	22
Surrounding Barrier (3 sides with Vertical Barrier)	37

Notes: *Marsh is 500' x 1,000', at low water under a variety of conditions using input data. Case 1: Mean tide level 0.2 ft below base point. Base point in land surface is square (3,2). Lower left corner of marsh. Tidal amplitude is 0.3 ft.

**Reverse direction = 44%.

saltwater intrusion inland (Gagliano 1973). Saltwater intrusion has occurred in Lake Borgne as a result of the GIWW, however, quantitative measurements are unavailable. Trace metals in the GIWW have been compared to maximum acceptable levels set forth by the EPA. In the Terrebonne Basin Management Unit, levels of arsenic exceeded EPA standards by 98 mg/l and mercury exceeded by 6.5 mg/l. Much of this excessive concentration may be caused by land runoff and subsequent concentration in the GIWW.

The Southwest Louisiana Canal in Lafourche Parish is another example of a canal affecting the marshlands. Doiron (1974) stated that the canal is eroding its banks at a rate of 16.3 feet per year. The spoil banks appear to be eroding most rapidly. The spoil banks are probably undercut by water flow and waves from ships and boat traffic. Overhanging parts of spoil banks fall into the canal, causing an increase of suspended solids. As erosion continues, other water drainage bodies might be intercepted and additional drainage patterns might be altered.

Shoaling usually occurs with erosion. Shoaling is an additional problem in the Southwest Louisiana Canal (Doiron 1974). It usually occurs at intersections of other water bodies to the canal. Water flow in the canals becomes changed and disrupted as a result.

Bayou Lafourche is an example of a naturally formed navigable waterway that now has been modified and its water flow artifically maintained by pumps at Donaldsville to support water traffic. It occupies an abandoned channel of the Mississippi River. The length of the bayou is about 90 miles beginning at Donaldsonville and continuing to the Gulf of Mexico. Some water enters the canal by runoff from a limited watershed but most is from pumps with a capacity of 260 cfs, which pump water into it from the Mississippi River. The primary commodities transported in Bayou Lafourche are listed in Table 6.

The effect of Bayou Lafourche on drainage may be the same as on artificially constructed channels. Spoil banks from dredging operations impede natural waterflow. In addition, tidal flushing in the lower reaches is changed. This may result in the cessation of tidal pond flushing and could eliminate nursery grounds of certain marine fauna. The normal flux of organic detritus from surrounding vegetation and organic wastes is lost because of spoil banks (U.S. Army Engineering District 1972).

Navigation

As in Bayou Lafourche, most navigable canals in Louisiana are used to a large extent to transport petroleum products. The U.S. Army Corps of Engineers maintains 170 miles of navigable canals in Louisiana. It is reasonable to assume that construction and maintenance of channels are carried out to a great extent in order to accommodate oil vessel traffic from OCS facilities. There is, then, an indirect effect on altered drainage patterns as a result of OCS-related navigation.

Transportation

The primary effect of OCS-related transportation on altered drainage is primarily in the construction of pipelines. Pipeline construction often requires the dredging of canals in which pipelines are placed. The spoil from pipeline dredging causes obstruction to natural drainage. In Lafourche Parish alone, there are at least 3.13 square

Table 6. Waterborne Commerce for Bayou Lafourche and Lafourche-Jump Waterway, Louisiana.

A. Total Traffic and Estimate of OCS Share

Year	Thousands of Tons	Per OCS Oil
1965	2,342	(38.8)
1966	2,067	40.0
1967	2,312	(40.0)
1968	2,333	(40.0)
1969	3,066	(40.0)
1970	2,431	40.0
1971	1,883	(40.0)
1972	1,590	(40.0)
1973	1,492	(40.0)
1974	1,552	(40.0)

B. Specific Commodity Breakdown for Waterborne Commerce in Bayou Lafourche and Lafourche-Jump Waterway, Louisiana (ibid).

		(short tons)
	Fresh fish except shellfish	887
	Shellfish	24,991
	Marine shell	390,508
X	Crude petroleum	441,618
	Sand, gravel, crushed rock	30
	Clay	17,371
X	Sulphur, liquid	134,203
	Nonmetallic liquid	300
	Sugar	40,815
	Molasses	2,269
X	Groceries	18
X	Ice	18,275
X	Timber, posts, poles, piling	485
	Sodium hydroxide	33,600
	Basic chemicals	1,576
	Gasoline	30
X	Distillate fuel oil	46,026
X	Building cement	2,673
	Nonmetallic minerals	622
X	Iron, steel pipe, tub	8,469
	Fabricated metals	232
	Machinery	13,112
	Ships and boats	2,558
	Misc. manufactured products	102,360
	Waste and scrap	500
X	Water	211,241
	Commodities	6,083
X	Waterway improvement mat.	5,600
		1,552,454

Ex = 914,608 58.9% of total traffic in 1974.

Table 6. Continued.

C. Net Primary Production Loss Due to Navigational Canals:

$$2.5524\ mi^2 = 1633\ acres = 6.6 \times 10^6 m^2$$

$$(6.6 \times 10^6 m^2)\ (0.85\ \text{wetland water ratio}) = 5.6 \times 10^6 m^2$$

$$(5.6 \times 10^6 m^2)\ (1 \times 10^3 gdwm^2) = 5.6 \times 10^9 gdw\ \text{per year}$$

Year	Thousands of Tons	Per Related to OCS	Net Primary Production Loss Related to OCS x 10^9gdw
1965	2342	(38.8)	2.17
1966	2067	40.0	2.24
1967	2312	(40.0)	2.24
1968	2333	(40.0)	2.24
1969	3066	(40.0)	2.24
1970	2431	40.0	2.24
1971	1883	(40.0)	2.24
1972	1590	(40.0)	2.24
1973	1492	(40.0)	2.24
1974	1552	(40.0)	2.24
			22.33

$$(22.3 \times 10^9 gdw)\ (0.40) = 8.9 \times 10^9\ \text{grams carbon}$$

$$(8.9 \times 10^9 gC)\ (10\ \text{kilocalories}) = 8.9 \times 10^{10}\ \text{kilogram calories}$$

		Loss Related to OCS Navigation	
		10 yrs	Per Year
$8.9 \times 10^{10} \div$	2.50×10^5 to 1.58×10^5	\$356,000 to \$563,291	\$35,600 to \$56,329

Source: U.S. Army Corps of Engineers 1974.

miles of pipeline canals (Table 7). All of these probably affect natural drainage patterns (Adams et al. 1976).

Eutrophication

Eutrophication, in general, refers to natural or artificial addition of nutrients to bodies of water and to the effects of the added nutrients (Rohlich 1969). The nutrients most responsible for lake eutrophication are phosphorus and nitrogen. Phosphorus is usually the initiating factor and is a good index for defining critical conditions and maximum permissible loads (Vollenweider 1971). Vollenweider establishes the critical specific loading level set between oligotrophic and eutrophic waters as around 0.2 - 0.5 total P $g/m^2/yr$. Phosphorus loading >0.4 $g/m^2/yr$ will usually signify eutrophic conditions in subtropical lakes (Brezenik and Shannon 1971; Craig and Day 1976).

Eutrophication results in progressive deterioration of water quality, the advent of algal blooms leading to the development of obnoxious species, the elimination of desirable (commercially important) species, and, eventually, to the development of anoxic conditions (Craig and Day 1976).

The specific sources of eutrophication in Lafourche Parish are urban runoff, sewage, drainage from agricultural land, and rainfall. Phosphorus in domestic sewage results primarily from human wastes and detergent. Runoff from urban areas is rich in phosphate and nitrate (Rohlich 1969). Drainage from agricultural land introduces phosphorus present in chemical fertilizers and animal excretion.

Present estimates of phosphorus input into Barataria basin, in

Table 7. Selected areas of pipeline canals and navigation canals presently in Lafourche Parish, La.

	Pipeline Canals	
East Lafourche Parish*	65 ft wide canals	1.6887
	130 ft wide canals	0.2361
West Lafourche Parish**		1.268
	Total	3.1928 square miles
	(equivalent to 2,043 acres or 8.3 x $10^6 m^2$)	
	Navigation Canals	
East Lafourche Parish*		0.8954
West Lafourche Parish**		1.657
	Total	2.5524 square miles
	(equivalent to 1,633 acres or 6.6 x $10^6 m^2$)	

Source:

*Adams et al. 1976.
**Adams et al. unpublished manuscript.

which the eastern half of Lafourche Parish lies, were determined by Craig and Day. The major water bodies, a section of each lying within the boundaries of Lafourche Parish, are Lac des Allemands, Bayou Chevreuil, Lake Salvador, and Little Lake.

The current total input of phosphorus into Lac des Allemands is 4.3 $g/m^2/yr$. The current phosphorus input into Lake Salvador is 1.5 $g/m^2/yr$. These are hypereutrophic conditions. By 1974, the eutrophic conditions began to affect the upper nursery zone where juvenile stages of various marine species spend the fast-growing phase of their life. Jaworski (1972) has already noted the decline of annual landings of the blue crab in the upper estuary, specifically Lake Salvador, and has attributed this in part to an increase in the amount and kinds of pollution in the upper estuary (Craig and Day 1976). The eastern half of Lafourche Parish contributes directly to this serious problem of eutrophication. This portion of Lafourche Parish exports an estimated 26 g/yr (10^6) of phosphorus or $\sim$10 percent of the total amount of phosphorus input by the entire basis population (Craig and Day 1976).

The phosphorus input for the entire parish was estimated by summing the input from sewage, urban runoff, and agricultural input. Agricultural input is determined by assuming the ratio of P input to agricultural land determined by Butler (1975) held for Lafourche Parish. Sewage input was estimated on a per capita basis (3.0 lbs/yr/person) (Keup and Mackenthur 1969). Urban runoff was also determined on a per capita basis (90 g/yr/person) (Stern and Stern 1969).

Total P input was computed as follows:

Sewage	∿ 98 metric tons/yr
Urban runoff	∿ 6 metric tons/yr
Agriculture	∿479 metric tons/yr
	∿583 metric tons/yr

The effects of OCS development on this problem can be measured on a per capita basis. The increase in population in Lafourche Parish from OCS development (approximately 5,000 persons) will directly affect phosphorus input from sewage and urban runoff.

Approximately 50 percent of the oil coming into Lafourche Parish is from OCS development. Of the selected two square miles of canals in eastern Lafourche Prish (east of Bayou Lafourche), one square mile could be contributable to OCS activities. The canals short-circuit the natural flow of nutrient-laden water into lakes and bays rather than allowing it to trickle through the wetlands. This direct flow of water from urban runoff, agriculture, and sewage goes directly into water bodies via canals causing hypereutrophic conditions in the lakes and bays.

Dredging of these canals resuspends the sediment particles in the water column and may reduce oxygen concentration temporarily as well as releasing other nutrients and compounds that could add to eutrophication problems.

Mineral extraction and navigation

The canals used for mineral extraction and navigation shunt nutrient-laden water directly into water bodies. This water would naturally trickle through the basin and would be taken up by wetland vegetation, increasing productivity. Because this process is short-circuited by artificial canals, the level of nutrients in water increases until blooms of "weed" plants choke waterways and produce conditions for massive fish kills. Dredging canals for pipelines resuspends nitrogen, phosphorus, and hydrocarbons from the sediment into the water column, attributing to the problem of eutrophication.

Transportation

Highway construction on many occasions cuts across the natural circulation pattern of wetlands, changing the hydrology of the system, and often creating eutrophic conditions.

Runoff from streets and highways contributes in large part to eutrophication of lakes and bays.

Subsidence

Subsidence, the lowering of the land surface relative to sea level, occurs throughout the coastal zone. Its causes are complex but can be contributed to several primary factors (Adams et al. 1976):

1) The eustatic sea level changes (.32 ft/century).

2) Regional subsidence caused by crustal downwarping (isostatic adjustment) from sedimentary loading.

3) Tectonic processes that include growth faulting (Jones 1969), folding, fracturing, and flowing are phenomena that develop within the thick sedimentary section.

4) Compaction* of sediment through dewatering processes:

    a) Differential consolidation owing to textural variability in the sediments.

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*Specific impact of OCS development in Lafourche Parish

b) Consolidation* of underlying sediments from weight of features such as natural levees, beaches, artificial levees--particularly when the features have been deposited over weak compressible foundations.

c) Local subsidence* of compressible materials through consolidation or displacement by objects such as buildings, pile structures, fills, bench marks, and tide gages.

d) Lowering of water table through extraction of groundwater, salt, or sulfur; also "reclamation" practices that employ diking, construction of water control structures, and drainage of lands for agriculture or flood protection.

These practices, cumulatively, become major concerns at the parish and state levels.

e) Extraction of oil, gas, sulfur, and water from salt domes is known to have resulted in subsidence.

5) Other phenomena and activities that contribute to subsidence through dewatering include the following:

a) Extended drought periods are thought to result in lowering the near-surface water, and compaction occurs within the dewatered, relatively thin layer.

b) Oxidation, hydration, and removal by wind are important factors in lowering of highly organic soil surfaces. This applies particularly to beaches along shorelines and coasts.

c) Marsh buggies* transversing marshland surfaces compact underlying material leaving permanent scars.

The spoil from canals used by OCS activity could cause consolidation of underlying sediment. Any population increase because of development contributes to the construction of housing and other facilities to provide for that population, which can cause land subsidence through consolidation or displacement of soil. Population increases could also contribute to the lowering of the water table through extraction of groundwater. The use of marsh buggies by OCS could also be a source of land subsidence.

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*Specific impact of OCS development in Lafourche Parish

Mineral extraction and navigation

The spoil banks created by the dredging of canals could cause subsidence by consolidating the underlying sediment. The use of marsh buggies in the marsh could also be a source of subsidence. Lowering of water table through extraction of salt, sulfur, and groundwater will cause subsidence.

Transportation

The building of roads and highways over weak compressible foundations will cause subsidence. A new highway is often a development corridor; new buildings along them may cause local subsidence of compressible material through displacement.

Erosion

The soft and unconsolidated nature of the soils in Louisiana's marshes leads to erosion when stressed. Channelization of canaling activities may result in the loss of plant communities actually responsible for holding a land mass together. If plants die from increased salinities (see section on salinity changes) or saltwater intrusion, the peaty soil is subject to erosion. As the area is eroded and deepens, they become less valuable as fish nursery areas (Yancy 1973). The amount of erosion varies with the amount of traffic, boat speed, marsh type, and the initial width of the canal (Nichols 1961). Also, uncontrolled drainage and runoff from highways may cause erosion.

In general, canal dredging is conducted for the specific purposes of providing access for mineral extraction industry or for providing routes for navigational traffic whereas roadways are constructed for the overland transportation of people and goods.

Mineral extraction

A study by Blackmon (unpublished data) on the Golden Meadow oil field illustrates how a canal widens over time. From Department of Agriculture 1:20,000 black and white photographs taken in 1940 and 1953 and a U.S. Corps of Engineers 1:20,000 black and white uncontrolled mosaic taken in 1969, canal areas were digitized. Over the 29-year period, the canal areas more than doubled (see Table 8). Craig et al. (in preparation) contribute most of this lost to the erosive action of boat-generated waves within the oil field.

The rate of erosion for canals dredged as the result of OCS activity could vary from or exceed those mentioned above. Different marsh types, amount of boat activity, and size all exert an influence on erosion rates.

Navigation

A recent study of canal erosion (Doiron 1974) conducted on the Southwestern Louisiana Canal illustrates how a navigational canal might be eroding away. Two factors were presented to explain the faster rate of erosion that is now evident within the area. They are:

1) The development of faster, more powerful boats and the resultant increase in tidal prism, and

2) With widening and deepening, a larger volume of water flows through the canal, resulting in greater shear stress and greater erosive ability.

Doiron's study indicates that the canal is widening at an average annual rate of 16.3 feet. The problem of erosion in Southwestern

Table 8. Canal widening over time in square miles.

	Canal	AE	BF	GC	CH	TOTAL
1940		.044	.008	.013	.026	.091
1953		.057	.013	.022	.034	.126
1969		.092	.017	.038	.040	.187

Source: Craig et al. unpublished MS.

Louisiana Canal is self-perpetuating. Although there is a continuous decrease in the slope of the canal banks (due to erosion) accompanied by an increase in dispersion energy, erosion increases because of the increased tidal prism (Doiron 1974).

Transportation

Although no data on erosion caused by highways exist, some generalizations can be made. With the increased amount of drilling offshore more onshore facilities will be needed. New facilities, if not located on existing highways will require the construction of new roadways. Also, some of the existing roadways will handle traffic directly related to the offshore drilling; for example, workers coming or leaving work and the shipping of materials to and from the coastal facilities.

Uncontrolled drainage and runoff from roadways cause erosion. If not checked the road could actually be undermined. And in the same manner that canals contribute to erosion by increasing saltwater intrusion, roadways can cut off or redirect the flow of fresh water into an area. This could raise the salinity, kill the plants, and speed up the erosion process.

Direct Land Loss

Land loss in the coastal zone is a problem with broad environmental and economic consequences. Land loss (i.e., land turned to water) is the result of many interacting factors such as flood control, navigation improvement, impoundments, canalization, channelization, and the biological and geological setting. Annual land loss in coastal Louisiana averages 16.5 square miles (Gagliano 1973).

The cumulative impact resulting from land loss includes changes in hydrology which contribute to (1) an increase in saltwater intrusion and eutrophication, (2) losses in storm buffer capacity, a decrease in tertiary treatment by marsh, and (3) diminishing nursery grounds for Louisiana's coastal fish and shellfish resources (Craig et al., in preparation).

Land loss in Lafourche Parish is as follows:*

Saline marsh	293 acres/yr
Brackish marsh	396 acres/yr
Fresh marsh	201 acres/yr
Swamp	53 acres/yr
Total	943 acres/yr

This land loss results in loss of primary production of the marshes and swamps (see Table 9). Marsh is more productive than water on the order of one magnitude. This loss of marsh and swamp has and will continue to have a direct impact on the economy of the area.

Canals contribute substantially to the land loss problem. Direct land loss results from the dredging of the canals, and there are numerous examples that demonstrate the widening of various canals over extended periods of time. Canals widen through usage, generally as a result of wave action created by boat traffic. Another important factor influencing this rate is marsh condition; the softer or more fluid and organic

*To obtain a general idea of land loss by vegetative type and management unit a composite map was created by Craig by superimposing Gagliano's (1970) map of land loss in the coastal zone over Chabreck's map of vegetative types in the coastal zone. This composite map was digitized to determine land loss in acres/year per vegetative type for Louisiana coastal zone (Craig et al. 1976). The map was again digitized specifically for Lafourche Parish.

Table 9. Productivity loss in Lafourche Parish.

<u>Saline marsh</u>
(assume 75% marsh; 25% water*)

293 acres loss/year ---------- 220 marsh acres loss/year

marsh-$(220 \times 4 \times 10^{3*}) \times 4 \times 10^{7*} = 3.5 \times 10^{13} \times 30$ years* $= 1.05 \times 10^{15}$

water-$(220 \times 4 \times 10^{3}) \times r \times 10^{6*} = 3.5 \times 10^{12} \times 30$ years $= \underline{.105 \times 10^{15}}$

Total Net Primary Production Loss = $.945 \times 10^{15}$

Gross Primary Production Loss (2xnet) = 1.89×10^{15}

<u>Brackish marsh</u>

396 acres loss/year ---------- 297 marsh acres loss/year

marsh-$(297 \times 4 \times 10^{3}) \times 4 \times 10^{7} = 4.8 \times 10^{13} \times 30$ years $= 1.4 \times 10^{15}$

water-$(297 \times 4 \times 10^{3}) \times 4 \times 10^{6} = 4.8 \times 10^{12} \times 30$ years $= .14 \times 10^{15}$

Total Net Primary Production Loss = 1.26×10^{15}

Gross Primary Production Loss = 2.52×10^{15}

<u>Fresh marsh</u>

201 acres loss/year ---------- 151 marsh acres loss/year

marsh-$(151 \times 4 \times 10^{3}) \times 4 \times 10^{7} = 2.4 \times 10^{13} \times 30$ years $= 7.2 \times 10^{14}$

water-$(151 \times 4 \times 10^{3}) \times 4 \times 10^{6} = 2.4 \times 10^{12} \times 30$ years $= .72 \times 10^{14}$

Total Net Primary Production Loss = 6.5×10^{14}

Gross Primary Production Loss = 13.0×10^{14}

<u>Swamp</u>

53 acres loss/year ---------- 40 marsh acres loss/year

marsh-$(40 \times 4 \times 10^{3}) \times 4 \times 10^{7} = 6.4 \times 10^{12} \times 30$ years $= 1.9 \times 10^{14}$

water-$(40 \times 4 \times 10^{3}) \times 4 \times 10^{6} = 6.4 \times 10^{11} \times 30$ years $= .19 \times 10^{14}$

Total Net Primary Production Loss = 1.71×10^{14}

Gross Primary Production Loss = 3.42×10^{14}

*1 acre = $4 \times 10^{3} m^{2}$

<u>Marsh</u>	<u>Open water</u>
4×10^{7} kilogram calorie per acre	4×10^{6} kilogram calorie per acre

30 years - time period for Gagliano land loss calculations (Gagliano 1971).

the marsh, the more susceptible it will be to erosion (Craig et al., in preparation).

Canal construction and dredging also cause marsh loss from spoil banks and the possible marsh deterioration and ponding that could result from the canal's impact on the surrounding area. In a study done by Nichols (1958) on canals in the Rockefeller Wildlife Refuge, the data suggests that the actual area of land that has its productivity altered is as high as five to six times that of the canal.

OCS is directly tied to the land loss problem by its canal construction, dredging practices, and pipelaying in Lafourche Parish. Of the two square miles of canals in existence in eastern Lafourche Parish, OCS is responsible for about half.

Mineral extraction and navigation

The canals needed for mineral extraction and navigation canals contribute to the land loss problem. There is the initial loss from dredging and the canals tend to widen over time. There is productivity loss from the spoil banks of the canals and frequently marsh deterioration and ponding in the surrounding area impacted by the canals. Canals that transcend marsh types may shunt saltwater into fresher marsh, creating diebacks and land loss.

Transportation

Often in the construction of highways, areas are dredged to make the highway foundation. Highways become development corridors, and marsh areas are drained and filled for housing construction.

Salinity Changes

The salinity patterns in Louisiana are very important according to Gagliano et al. (1970) with the transition from ocean salinities (34 to 36 ppt) to freshwater salinities (<5 ppt) being very gradual. Gagliano et al. (1973) suggests that one of the factors controlling the delicate balance of the natural system is the sinuosity of backswamp drainage and tidal networks. The dredging of long, deep canals traversing several marsh types for navigational and mineral extraction purposes has accelerated runoff, saltwater intrusion, and water exchange (Gagliano et al. 1973). The construction of levees and highway embankments may result in changed direction of water flow, damming of water flow, and increased velocity of saltwater flow into the marsh and increased flow through the marshes to the sea (St. Amant et al. 1958).

Because many estuarine areas are partially isolated or far removed from a saltwater source, they have low salinities. As a result, they provide nursery habitats for few species. The opening up of these areas by canals may increase the salinities permitting more species to be accommodated. However, the salinity may increase to the point as to alter the habitat adversely. Chapman (1968) reports that the improvement of habitat conditions by saltwater intrusion to a specific area is often accompanied by habitat deterioration from excessively high salinities.

Mineral extraction

Data were not available on salinity changes in Lafourche Parish as a result of canaling operations. However, from usual observations, Stone (1976) says that in the area around Clovelly salt dome, the proposed site for the LOOP onshore terminal, vegetational changes suggest that saltwater intrusion is occurring.

If the underground storage of oil in salt domes becomes more important in the future, these domes will need to be leached out. The amount of fresh water withdrawn for this purpose may raise salinities in the area of operations. For example, at the Clovelly dome it is estimated that fresh water withdrawal for leaching will cause inshore salinities to increase in the Barataria Bay an estimated 2 to 3.5 percent, which results in an inland intrusion of each isohaline by approximately 500 to 1000 feet (Light 1976).

Navigation

Documented evidence of changing salinity patterns as a result of dredging navigation canals in Lafourche Parish has not been found. To illustrate the possible effect of canals on saltwater intrusion, the Mississippi River-Gulf Outlet (MRGO) will be examined. Salinity in the MRGO area was probably changed by:

1) The mixing of channel water with that of surrounding bayous through their intersection points.

2) Movement of denser and more saline water from the deeper layers of the channel into Lake Ponchartrain, which also raises the salinities in Lake Borgne.

3) Raising of salinities through the effect of occasionally abnormal high tides which would be heightened by the close proximity of highly saline waters in the channel.

The MRGO has helped high-salinity waters from the Gulf of Mexico to penetrate and disperse throughout nearby marsh and shallow bays (Chapman 1968). Rounsefell (1964) predicted, with no control in the Gulf outlet channel, that the salinity of Lake Pontchartrain would change approximately 4.3 ppt in years of high fresh water inflow and 5.5 ppt in years of low inflow.

Transportation

As mentioned above, highway embankments can act as dams, lowering the amount of fresh water entering the marsh area. No data for Lafourche Parish exist. However, it is reported by Copeland (1974) that the construction of a highway in the coastal area of Louisiana and Mississippi has resulted in the separation of inland areas of the marsh from the lower marsh areas. This roadway has altered circulation patterns and prevents the inflow of fresh water from inland sources. No other facts about this roadway are given.

Turbidity

Turbidity in the ambient water increases primarily as a result of dredging or other diggings. Construction of offshore oil structures can increase turbidity, but since the substrate offshore has a high sand content and currents are present, the effect of turbidity on the biota is probably not as severe as in estuaries. This is because larger particles settle out faster than fine particles. We believe that the major impact of turbidity from OCS activity is due to dredging of canals in the estuaries. Dredging is done primarily for navigation canals and the routing of pipelines. It is unnecessary to separate the impact of turbidity between mineral extraction, navigation, and transportation, since the effect is the same for each. The action of motor boats and other ships definitely increases local turbidity but we can not estimate accurately this effect at this time.

During dredging sediments become suspended in the water column causing substantial increases in turbidity. The coarser particles in suspension quickly settle while fine particles probably remain suspended indefinitely (Conner et al. 1976).

The effects of turbidity in estuaries and wetlands may impair the feeding of many filter-feeding organisms such as shellfish; it may smother benthic plants and animals; or it may impair fish spawning; it may decrease photosynthesis. Although oysters can feed in turbid water, they normally cease pumping upon large increases in turbidity (Loosanoff and Tommers 1948). Odum (1963) noted that benthic communities closest to the dredging area become covered with silt. Oysters that are completely covered die (Ingle 1952). It should be noted that recent studies indicate that not all benthic organisms are killed when buried in sediment. Some are able to burrow through it (U.S. Army Engineer Waterways Experiment Station 1975).

Turbidity has also been attributed to fish kills (Lindall et al. 1972). Suspended particles clog fish gills and cause suffocation.

Newly suspended fine materials under certain conditions can be carried for long distances and may form a false bottom that will not support benthic animals (Hollis et al. 1964). Mackin (1961) reported silt in a shallow Louisiana estuary is carried and deposited as far as 1,300 feet from the dredge.

In a natural state, Louisiana's estuaries are relatively turbid. Measurements by Barrett (1971) at 82 stations in marshes and estuaries found 23 percent of secchi disc readings less than one foot and 70 percent less than two feet. Increased turbidity from dredging can be detected even in turbid waters, but the degree of increase is difficult to measure.

Any construction project that disturbs the sediments will result in at least short-term negative effects. Projects that might cause long-term suspended sediments could have far-reaching effects on estuarine inhabitants (Conner et al. 1976).

Disruption of Flora and Fauna

With the increased drilling offshore and the construction of offshore oil ports, more facilities and pipelines will be needed onshore. The construction of onshore terminals, storage sites, canals, roads, etc., in the marsh environment all disrupt the area directly involved and thus disrupt the flora and fauna.

The plant communities of coastal Louisiana are very productive and support a host of consumer types. Therefore, the loss of some of the marsh through dredging, filling, and spoil disposal results in a loss of productivity of that area and the loss of the area for use as a habitat.

Mineral extraction

The construction of onshore terminal facilities and associated canals and storage units will disrupt the flora and fauna to some extent. Wherever a terminal is constructed, there is a complete loss of all biological taxa, ecosystem functions, and habitats within the project area. Likewise, there is a loss of plant and detritus production and plant biomass along pipeline and roadway routes.

In regard to the proposed construction of a superport terminal and pipeline system at Clovelly salt dome in Lafourche Parish, the proposed terminal will affect 450 acres of land with 4 acres actually being filled with sand and shell for the terminal. Also, four canals will be constructed on top of the dome and the spoil will be deposited on the side of the canal or in a large diked disposal area. Since the oil is to be stored underground, the dome will have to be leached out, thus requiring a large brine reservoir and the discharge of brine water offshore into the Gulf. The superport project will use at least two parallel pipelines onshore running from marine terminal offshore to the onshore terminal at Clovelly salt dome and finally on to St. James, La. Most of the onshore 80-mile pipeline is planned to be located in Lafourche Parish.

At the Clovelly site, canal and brine pit construction will result in a loss of about 217 acres. As a result of this construction, all or most phytoplankton, selected algae, vascular flora, and aquatic macrophytes will be destroyed. A permanent loss of plant production of 1,900 tons/yr is estimated. Most of all, the zooplankton will also be destroyed and permanently lost (Stone 1976). A small acreage for the shore pumping station will also be lost to the biological production.

The terminal construction will probably cause the destruction of most of the meiofauna, epi-macrofauna, and in-macrofauna of the disturbed sediments. Potential nekton losses for the Clovelly site are estimated at about 2,000 pounds. The insect fauna is likely to be increased as a result of the protection levees, which create a more terrestrial habitat (Stone 1976).

The laying of the 80-mile pipeline will destroy approximately 1,900 acres of various types of vegetation and many animal forms that use the vegetation as a habitat. There will probably be a temporary loss of phyto- and zooplankters amounting to about 1.9×10^{15} and 2.0×10^{11} individuals, respectively. Total permanent loss of primary production in the marshes amounts to 1,048 tons per year. Temporary production losses in the swamp forest are 2,814 tons per year (Stone 1976).

The total number of benthic individuals that will probably be destroyed along the pipeline route is about 1.8×10^{10}. About 650,000 pounds of nekton will be destroyed or displaced along with about 400 to 450 wading and waterfowl birds. Construction costs imposed on the environment as a result of the superport project are estimated to range between 4.6 and 7.3 millions of dollars (Stone 1976).

Although the impact of this one project might not be significant when viewed as a part of the whole parish, cumulative effect of completed and proposed projects should be considered.

Navigation

Dredging to create, or deepen and widen a canal for navigational use also disrupts the flora and fauna by altering natural water flow patterns, destroying habitats, and polluting coastal waters (Clark 1974). Hydraulic dredges, commonly used in navigational waters, cause the least disturbance from release of polluting sediments but have a high potential for disturbance where the spoil is discharged.

In Lafourche Parish the two main navigational canals are the Gulf Intracoastal Waterway (approximately 31 miles long within the parish) and the Southwestern Louisiana Canal (approximately 10 miles long). In addition, there are 2.55 square miles of selected navigation canals in Lafourche Parish (Table 7). Gane (personal communication) reports that although no quantitative data exist on the amount of area occupied by spoil, there is at least a 1:1 ratio of canal area and spoil area. This means that there is at least 2.55 square miles of spoil disposal areas.

Transportation

Roadways not only alter the flora and fauna directly within the right-of-way, but also induce new forms of land use along the road corridor, which will also affect the area. The removal of unsuitable marsh soils by excavation and disposal on marsh areas destroys habitat, releases toxic substances, and depletes oxygen in the water. The use of fill material also destroys habitats. Roads may act as dams (if not properly supervised) that block natural water flow and degrade wetlands. Sections of marsh may become impounded as a result of being cut off from tidal flow by highway fill (Clark 1974).

The amount of marsh acreage loss as a result of highway construction is dependent upon a variety of factors relating to the individual project. For Louisiana highways, specific minimum right-of-way widths are required and it may be assumed that all of the right-of-way will be detrimentally affected. Elevated roadways destroy less area of natural habitat because the only dredge and fill operations occur in setting piles.

In 1974, Lafourche Parish reported that there were:

269.21 miles	State system roads
249.32 miles	Local rural roads
71.98 miles	City streets
43.75 miles	Unincorporated streets
634.26 miles	Total miles in the parish

Right-of-way widths vary depending upon number of lanes, amount of traffic, and width of lane, shoulder, and median. The minimum design standards specify right-of-way widths varying from 20 feet for roads traveled by less than 100 cars per day to 300 feet for roads traveled by over 12,000 per day (see Table 2). Therefore, from 2.4 square miles to 36 square miles of Lafourche Parish are incorporated into road right-of-ways. It must be noted there that the total number of miles given above only represents those roads that are from 1 to 6 years old. Therefore, more area has been affected.

If the amount of traffic due to OCS production were known, or if the amount of roads constructed for the specific purpose of OCS onshore activities were known, the amount of habitat lost within the parish could be proportioned.

CHAPTER 5

QUANTITATIVE ESTIMATES OF SELECTED ENVIRONMENTAL IMPACTS IN LAFOURCHE PARISH RELATED TO OCS OIL AND GAS ACTIVITIES

Methodology

Environmental impacts result from economic activities. In the case of mineral extraction, transportation, and navigation as required for Outer Continental Shelf development, the primary environmental impacts occur in onshore land uses, changes in air and water quality, and as a result of these, changes in the quality of life. These economic activities require additional governmental services, which in turn affect the use of land, water, and air. Accurate impact estimates require economic baseline data and we believe that these are best obtained by means of extensive field surveys via questionnaires and interviews. Though there were beginning efforts made toward such survey work in Lafourche Parish, it was not enough to base the entire study upon. Therefore it was necessary to make impact estimates from some secondary data.

One set of secondary data that is directly related to OCS activities is the amount of crude oil and gas that is produced offshore of Lafourche Parish and is pumped onshore through pipelines into the parish. Table 10 lists the total amount of crude oil and natural gas produced in Lafourche Parish and offshore for selected years from 1957 to 1973; the percentages of OCS oil and gas are also listed. Table 11 lists the same type of data for the state of Louisiana for selected years. The percentages of OCS oil and gas for Lafourche Parish and the state follow approximately the same pattern; OCS development initially accounted in the

Table 10. Amount of crude oil (barrels) and natural gas (cubic feet) for selected years that is produced onshore and in federal waters offshore for Lafourche Parish, La.

Crude Oil

	Total	OCS	OCS Percentage
1957	33,170,696	57,127	0.17
1958	31,097,147	392,983	1.26
1960	42,152,741	7,110,438	16.80
1963	68,647,552	57,969,625	84.40
1964	70,803,012	26,665,635	37.60
1966	87,620,519	35,099,576	40.00
1970	117,674,244	47,613,402	40.00
1973	96,892,707	43,870,647*	45.20
Cumulative Total	1,403,249,792	700,219,826	

Natural Gas*

	Total	OCS	OCS Percentage
1957	89,680,947	4,627	0.005
1958	112,823,306	20,588	0.010
1960	148,489,465	49,748	0.030
1963	195,511,515	18,105,326	9.200
1964	198,871,254	16,190,339	8.100
1966	234,680,661	8,151,338	3.400
1970	296,994,070	40,262,951	13.500
1973	336,179,052	60,744,573*	18.100
Cumulative Total	2,977,788,641	143,529,490	

Notes: *All natural gas goes to Tennessee Gas Pipeline Co., Tenneco Oil Co., and United Gas Pipeline Co.

Source: Dept. of Conservation, 1957, 1958, 1960, 1963, 1964, 1966, 1970, 1973. Mr. McBee, USGS New Orleans, Personal communication.

Table 11. Amount of crude oil (barrels) and natural gas (cubic feet) for selected years that is produced onshore and offshore Louisiana.

OIL PRODUCTION

Thousand Barrels

Year	Total La.	Total Offshore	%	State	%	OCS	%
54	246,558	15,926	6.4	12,581	5.1	3,345	1.3
55	271,010	25,731	9.5	19,040	7.0	6,691	2.4
56	299,421	40,906	13.7	29,861	10.0	11,045	3.7
57	329,896	52,835	16.0	36,984	11.2	15,851	4.8
58	313,891	47,381	18.3	38,697	12.3	18,684	5.9
59	362,666	72,793	20.1	42,060	11.5	30,733	8.5
60	400,832	88,122	22.0	52,348	13.1	35,774	8.9
61	424,962	103,197	24.3	54,739	12.0	48,458	11.4
62	477,153	126,801	26.6	61,334	12.9	65,467	13.7
63	515,057	149,087	29.0	61,408	11.9	87,679	17.0
64	549,698	173,709	31.6	66,393	12.1	107,316	19.5
65	594,853	199,293	33.5	76,798	12.9	122,495	20.6
66	674,318	243,080	36.0	98,115	14.5	144,965	21.5
67	774,527	284,033	36.7	96,202	12.4	187,831	24.3
68	817,426	329,922	40.4	110,926	13.6	218,996	26.8
69	844,603	365,691	43.3	101,866	12.1	263,825	31.2
70	906,907	398,378	44.0	63,740	7.0	334,637	36.9
71	935,243	448,772	48.0	62,828	6.7	385,944	41.3

Table 11. Continued.

GAS PRODUCTION

Millions of Cubic Feet

Year	Total La.	Total Offshore	%	State	%	OCS	%
54	665,070	81,325	12.2	63,433	9.5	17,892	2.7
55	782,328	121,279	15.5	37,596	4.8	83,683	10.7
56	773,949	136,527	17.6	45,053	5.8	91,474	11.8
57	775,009	160,472	20.7	69,100	8.9	91,372	11.8
58	783,009	233,967	29.9	116,082	14.8	117,885	15.1
59	846,110	329,280	38.9	122,213	14.4	207,067	24.5
60	875,567	408,388	46.6	110,273	12.6	298,115	34.0
61	931,176	458,481	49.2	103,942	11.1	354,539	38.1
62	1,010,137	588,361	58.2	114,739	11.3	473,622	46.9
63	1,143,707	706,545	61.8	180,337	15.8	526,208	46.0
64	1,352,980	783,474	57.9	161,743	12.0	621,731	45.9
65	1,431,836	871,124	60.8	225,535	15.7	645,589	45.1
66	1,562,075	1,265,899	81.0	300,511	19.2	965,388	61.8
67	1,754,603	1,655,223	94.3	567,961	32.4	1,087,262	61.9
68	2,096,976	2,057,291	98.1	643,324	30.7	1,413,967	67.4

Source: U.S. Dept. of Interior 1975.

1950s for 1 to 9 percent of the total production in the state and parish and, thereafter, progressively increased to its present level of over 40 percent of the total.

Impacts from employment and/or population increases

There are no refineries or petrochemical plants in Lafourche Parish, so the most important environmental impacts in the Lafourche-Grand Isle area are probably because of population increases brought on by industrial jobs in the OCS development activities.

Table 1 indicates that in 1972, 1,625 men and women were engaged in "mining" occupations in Lafourche Parish. Some 2,500 men and women were involved in "transportation, communication, and utilities" occupations--with the large percentage of that number being employees of boat rental or tugboat companies providing transportation service to the offshore oil industry. Another 2,025 men and women were involved in manufacturing, some of which was shipbuilding, sheetmetal work, and the like--an impact of the development of OCS oil fields.

Table 12 lists employment data modified from Woodward-Clyde (1975) to estimate the impact of the production of 510,000 barrels per day for the development of an offshore oil and gas field. Approximately 1,600 persons are directly necessary for this production. Using the methodology of the Louisiana Offshore Terminal Authority and Kaiser Engineering, we have assumed an induced employment for a production rate of 510,000 barrels per day to be an approximate addition of 1,600 persons. Thus for a production rate of 510,000 barrels per day, one man is needed for every 157 barrels produced.

Table 12. Data used for estimating employment for Outer Continental Shelf (OCS) development off Lafourche parish, Louisiana.

1. Direct employment estimates for a proposed OCS project

		# Men
a.	Construction and Drilling: (24 drilling rigs)	(1500)
b.	Offshore Production: 34 platforms, 15 oil wells each (510,000 bbls per day), 3 gas wells each, 16 men per platform	544
c.	Onshore Support: (2 men per 1000 barrels)	408
d.	Onshore Office Support:	126
e.	Gas Production Personnel:	100
f.	Pipeline Terminals (3 each):	51
g.	Service Personnel Support*:	398
		(3127)
		1627

$\frac{510{,}000 \text{ bbls per day}}{1627}$ = 313 Barrels of oil per day per man (production employment)

*Includes personnel for 3 large helicopters, 4 small helicopters, 4 crew boats, 3 cargo boats, 2 tug boats, and 17 standby field boats.

Total wages are estimated to be:	$1,896,000	(Production & Service)
	614,000	(Construction & Drilling)
	$2,510,000	

2. Induced employment* for item 1: 1627
Direct employment estimate: 1627
Total employment: 3254 per production of 510,000 bbls day^{-1}

$\frac{510{,}000}{3254}$ = 157 barrels per day per man

(= 57307 barrels per year per man)

*A multiple of 9 is used to estimated induced employment following Louisiana Offshore Terminal Authority and Kaiser Engineering (1976).

Source: Woodward and Clyde, 1975.

Table 13 lists estimates of OCS employment for Lafourche Parish on the basis of the total OCS oil production that flows through the parish, i.e., 700 million barrels of oil. Since approximately one man is needed for every 157 barrels produced per day, this means that 4.6×10^6 man-days produced this oil, and this is equivalent to 719 men per year.

We have assumed induced employment would require an additional 719 persons for a total of 1,438 jobs related to OCS activities. Statistics made available by the Louisiana Department of Commerce and Industry (personal communication) indicates a 3.5 person-per-job increase in the population of an impacted area. Therefore 1,438 jobs created by OCS activities in Lafourche Parish would be equivalent to a population increase of 5,033, or between 7 to 10 percent of the total population of Lafourche Parish.

The increased burden upon the environment, brought about by a population increase of 5,000 persons can be measured in the change in land-use patterns. Using Kaiser Engineering and Louisiana Offshore Terminal Authority (1976) estimates (Table 14) the population increase of 5,000 in Lafourche Parish has probably required approximately 308 acres for OCS-related residents acreage and another 308 acres for OCS-related industrial sites.

Similarly, the burden of this population increase shows up in services such as the water system. As mentioned before, the Lafourche Waterworks District No. 1, in Lockport, served 16,000 households in June 1976. That was up from 5,118 households served in 1955. When the waterworks plant was designed in 1955, engineering analysis of south Lafourche Parish indicated the plant would be of sufficient capacity to

Table 13. Estimates for Direct and Induced Employment Due To Outer Continental Shelf (OCS) Activities in Lafourche Parish, Louisiana.

	# Men
1. Direct Employment:	719

(700×10^6 bbls of OCS oil) ÷ (157 bbls per day per man) = 4.4×10^6 man days

and

(4.4×10^6 man days) (12,000 man years) ÷ (17 years of OCS) = 719 men per year

2. Induced Employment: (9 Multipler)	719
Total	1438

Table 14. Estimates of Selected Environmental Impacts Due to an Estimated Total Population Increase of 5047 Individuals in Lafourche Parish, Louisiana Related to Outer Continental Shelf (OCS) Activities.

1.	<u>Educational Facilities</u>:	
	a. Local schools $\left(\frac{285}{1000}\right)$	: 1438 students
	70% elementary 15% junior high 15% senior high	
	b. Higher education $\left(\frac{44}{1000} = \frac{X}{1438}\right)$	: 222 students
	c. Vocational $\left(\frac{50}{1000} = \frac{X}{1438}\right)$	: 252 students
2.	<u>Highways and Streets</u>	: Sufficient commuter data not available
3.	<u>Medical and Health Facilities</u>:	
	a. Hospitals $\left(\frac{4 \text{ beds}}{1000} = \frac{X}{1438}\right)$	: 20 hospital beds
4.	<u>Police Protection</u> $\left(\frac{2}{1000} = \frac{X}{1438}\right)$	: 10 policemen
5.	<u>Water and Sewage Facilities</u>	: Sufficient data not available
6.	<u>Libraries</u> $\left(\frac{1000 \text{ volumes}}{1000} = \frac{X}{1438}\right)$	: 5047 volumes
7.	<u>Parks and Recreation</u> $\left(\frac{25 \text{ acres}}{1000} = \frac{X}{1438}\right)$	: 126 acres
8.	<u>Local Government</u>:	
	a. Employees $\left(\frac{6}{1000} = \frac{X}{1438}\right)$	: 30 government workers
	b. Building 300 ft^2 per employee	: 9000 square feet
9.	<u>Residential acreage</u> $\left(\frac{61 \text{ acres}}{1000 \text{ population}} = \frac{X}{1438}\right)$	: 308 acres
10.	<u>Industrial acreage</u> $\left(\frac{61 \text{ acres}}{1000 \text{ population}} = \frac{X}{1438}\right)$	: 308 acres

Source: Louisiana Offshore Terminal Authority and Kaiser Engineering 1976.

serve the needs of the people in the district until 1980. However, it has been necessary to triple the size of the plant, and there is serious consideration being given to another capacity expansion. The consumption in gallons for the month of June 1976 was 143,184,700 gallons, as compared to 14,428,000 gallons in the same month, 1955. It must also be stressed that Waterworks District No. 1 sells fresh water to consumers in Grand Isle, which is not Lafourche Parish, and it also sells water to oil companies for use in offshore platforms and rigs. An average monthly consumption for 1975 was: 1.2 million gallons, Shell Oil Company; 3.5 million gallons, Gulf Oil Company; 1.25 million gallons, Chevron Oil Company; and 270,000 gallons, Texaco Oil Company (Eldon J. Breaux, General Manager, Lafourche Parish Water District No. 1, personal communication 1976).

Although it is not possible at this time to measure the exact ecological impact, we must consider too that in southern Lafourche Parish, with approximately 16,000 households, there is no sewage system. All residents use septic tanks, as do many nearby businesses. In times of heavy rainfall, when drainage is a problem, many residents report sewage in ditches and fields. This may pose a serious health hazard sometime in the future.

Table 14 gives a list of other effects upon the society of Lafourche that are a result of OCS oil and gas development-related population increases.

Pipeline canals

The OCS oil and gas has to flow through onshore pipelines in areas of open water that were once marsh wetlands; the areas of selected pipeline canals found in Lafourche Parish are listed in Table 7; there are 3.1928 square miles (or 2,043 acres) of these pipelines in Lafourche Parish. We have assumed that the environmental impacts of OCS oil and gas to pipeline areas in the marsh are proportional to their percentage of total flow through these selected pipelines in the parish. Thus, for example, in 1957 (Table 15) OCS oil accounts for 0.17 percent of the total pipeline impact and OCS gas accounts for 0.005 percent of the total; in 1973 oil accounts for 45.2 percent of the total and gas for 18.1 percent of the total.

In order to estimate losses because of OCS oil and gas development it is necessary to calculate the amount of net primary production that would be produced by marsh grass if the pipeline had not been dug. Table 16 lists three steps for calculating the loss if one acre (4047 m^2) of marsh grass is destroyed. Production by marsh grass is about five to ten times greater than production by an open water system (i.e., on the average, 1,000 g dry wt/m^2/yr compared to 100 g dry wt/m^2/yr).

This net primary production is the energy equivalent of between \$41 and \$68 of fossil fuel. Thus this is the approximate loss of net primary production in dollars per acre for one year if the grass is destroyed, as it is when pipelines are placed in the marsh wetlands. Table 15 lists the necessary steps for estimating the dollar equivalent of net primary production loss due to pipeline canals or ditch usage. The loss from OCS activity is calculated for each year from 1957 through 1971 and then it is summed over 15 and 17 years and then converted to a dollar

Table 15. Methodology for estimating environmental impact of pipeline canals and navigational canals in Lafourche parish due to Outer Continental Shelf (OCS) activities.

1. <u>Pipeline canals in Lafourche parish:</u> 3.1928 square miles

2. <u>Net Primary Production loss related to OCS oil due to pipeline canals use:</u>

$3.1928\ mi^2 = 2043\ acres = 8.3 \times 10^6 m^2$
$(8.3 \times 10^6)\ (0.85\ \text{wetland water ratio}) \cong 7 \times 10^6 m^2$
$(7 \times 10^6 m^2)\ (1 \times 10^3) = 7 \times 10^9$ grams dry organic per yr.

Year	% Oil Flow from OCS*	Net Primary Production Loss x 10^9gdw
1957	0.17	0.012
1958	1.26	0.088
(1959)	(9.03)	0.651
1960	16.80	1.176
(1961)	(39.33)	2.753
(1962)	(61.86)	4.330
1963	84.40	5.908
1964	37.60	2.632
(1965)	(28.80)	2.716
1966	40.00	2.800
(1967)	(40.00)	2.800
(1968)	(40.00)	2.800
(1969)	(40.00)	2.800
1970	40.00	2.800
(1971)	(40.00)	2.800
		37.06

*(values in parentheses are estimated)

$(37 \times 10^9 gdw)\ (0.40) = 14.8 \times 10^9$ grams carbon

$(14.8 \times 10^9 gC)$ (10 kilograms calories) $= 14.8 \times 10^{10}$ kcal

		Loss Related to OCS Oil	
		15 yrs	Per Year
$(14.8 \times 10^{10} kcal) \div$	(2.50×10^5) to (1.58×10^5) $\cong$	\$592,000 to \$937,000	\$39,466 to \$62,466

3. <u>Net Primary Production loss related to OCS natural gas due to pipeline canal use:</u>

$3.1928\ mi^2 = 2043\ acres = 8.2 \times 10^6 m^2$
$(8.3 \times 10^6 m^2)\ (0.85\ \text{wetland water ratio}) \cong 7 \times 10^6 m^2$
$(7 \times 10^6 m^2)\ (1 \times 10^3 gdwm^2) = 7 \times 10^9$ grams dry organic per year

Table 15. Continued.

Year	% Gas Flow from OCS*	Net Primary Production Loss x 10^9 gdw
1957	0.005	0.0003
1958	0.010	0.0007
(1959)	(0.020)	0.0140
1960	0.030	0.0210
(1961)	(3.090)	0.2163
(1962)	(6.150)	0.4305
1963	9.200	0.6440
1964	8.100	0.5670
(1965)	(4.700)	0.3290
1966	3.400	0.2380
(1967)	(5.92)	0.4144
(1968)	(8.44)	0.5908
(1969)	(10.96)	0.7672
1970	13.500	0.9450
(1971)	(15.030)	1.0521
(1972)	(16.560)	1.1592
1973	18.100	1.2670
	*(values in parentheses are estimated)	8.6565

$(8.6565 \times 10^9 \text{gdw})\ (0.40) = 3.5 \times 10^9$ grams carbon

$(3.5 \times 10^9)\ (10 \text{ kilocalories}) = 3.5 \times 10^{10}$ grams carbon

			Loss Related to OCS Gas 17 yrs	Per Year
3.5×10^{10} ÷	2.50×10^5 to 1.58×10^5	$\cong$	\$140,000 to \$221,000	\$ 8,235 to \$13,000

loss. Thus the 15-year environmental loss for selected OCS oil pipeline usage is between $592,000 and $937,000, or between $39,000 and $62,000 per year. Loss for use of selected OCS gas pipelines is estimated at between $140,000 and $221,000 over 17 years, or between $8,200 and $13,000 per year. A more accurate assessment could be made if data on specific flow rates for each pipeline were available.

Losses due to navigational canals

OCS activities require service support by means of boats and ships. Table 6 lists the total water commerce for 1965 through 1974 in Bayou Lafourche and Lafourche-Jump Waterway. Specific commodities are listed for 1974. However, more data are necessary in order to prorate the amount of traffic that is related to OCS activities. We have used the percentage of oil production for Lafourche as a guide to making a first and very rough estimate. Table 7 lists the amount of selected navigational canals in Lafourche Parish; there are 2.5524 square miles (or 1,633 acres). Total loss of net primary production is calculated for each year as done for pipeline canals and summed over 10 years. The total loss is estimated to be between $356,000 and $563,000 or approximately $36,000 to $56,000 per year due to OCS-use of selected navigational canals.

Potential oil spills and damages

OCS operations off Louisiana have resulted in two major oil spills. One occurred just off and east of the Mississippi River delta; the other occurred just southwest of Bayou Lafourche (reviewed by Stone 1972). In both cases, only a small amount of oil entered the coastal marshes and the resulting damage was apparently minor. Stone et al. (1975) calculated that if 2,000 tons of oil--a major spill--entered Louisiana coastal marshes, it could under certain conditions damage up to approximately 12,000 acres of marsh grasses. Using the data listed in Table 16, this damage could be approximately equivalent to between $500,000 to $800,000 for the first year. Assuming it would take five years for the marsh wetlands to completely recover and that 25 percent of the marsh recovers each year, then the total loss from a 2,000-ton oil spill could range between $1,250,000 and $2,000,000.

Discussion, Suggested Guidelines for Mitigation and Other Management-Related Information

Assumptions and accuracy of impact estimates

We view our cost estimates of the environmental impacts of OCS activities to Lafourche Parish as preliminary and incomplete estimates. The methodology is more important, at this stage, than the accuracy of the data. Our methodology assumes that if OCS-related activities destroys marsh grass, and there is no recovery, then this is a cost imposed on the environment. We have only calculated the loss of net primary production; other costs to the environment are the loss of a certain amount of the total waste assimilation capacity of the wetlands in the parish. This waste assimilation capacity is the ability of marsh grass to remove undesirable chemicals in the local waters and, to some degree, in the local air. The total waste assimilation capacity of each parish and its subenvironments needs to be calculated.

We believe that some of these preliminary estimates are probably minimal; for example, they do not incorporate the spoil bank area near

Table 16. Methodology for estimating primary production loss when vegetation is destroyed.

1. Net Primary Production Rate: 1000 grams dry weight per m^2 per year

2. Area of Impact: Assume marsh is 85% grass and 15% is water bodies. Thus if 1 acre is impacted then 0.85 acre is marsh.

   (1 acre $\cong$ 4047 m^2 and 85% of this is equal to 3440 m^2.)

3. Biological Damage to One Acre:

   a. (1000 gdw) (3440 m^2) = 3,440,000 grams of dry weight of plant material destroyed per 1 acre per year.

   b. One gram dry weight organic material is approximately 40% carbon. Thus:

   3,440,000 x 0.40 = 1,376,000 grams carbon lost per one acre per year.

   c. One gram carbon is approximately equivalent to 10 kilogram calories. Thus:

   (1,376,000) x 10 = 10,387,000 kilogram calories lost per one acre per year.

   d. One dollar is approximately equivalent to 158,000 kilocalories of net primary production. Thus:

$$10{,}376{,}000 \div \left.\begin{matrix} 250{,}000 = \$41.50 \\ \text{to} \quad\quad \text{to} \\ 158{,}000 = \$67.70 \end{matrix}\right\} \text{ loss per acre per year.}$$

Source: *Zuchetto 1975. **Gilliland 1975.

the pipelines and navigation canals, nor have we estimated the cost of water treatment imposed on the environment by the septic tanks in south Lafourche.

We have assumed that the amount of OCS oil and gas that entered Lafourche is proportional to its environmental impact. These data need to be detailed in terms of what parish pipelines the OCS oil and gas goes through and when they go through. This information might make our preliminary estimates more accurate.

In addition, the pipeline data listed in Table 15 are derived from what was visible on aerial photographs and thus they do not represent total pipelines in Lafourche Parish--rather those pipeline canals that have not recovered and are visible on photographs. Complete data on the amount of pipelines are necessary for accurate impact estimates.

Suggested guidelines for mitigation

Guidelines for mitigating the environmental impacts of OCS-related activities in Lafourche Parish are suggested and discussed below.

1) The costs of environmental services such as the water and air quality of the parish and certain governmental services as required by OCS activities should be accurately calculated and assessed.

2) All pipeline canals should be restored as much as possible to their natural and original condition. Pipeline canals change a marsh grass system into an open water system and the latter is approximately 2 to 10 times less productive than the former. Water areas also increase the amount of area open to wind fetch and as a result might increase the rate of land erosion and loss. In addition, spoil banks are often deposited next to the pipeline canals and these banks can and do cause severe change to the local patterns of water circulation.

3) Abandoned facilities or those no longer in use should be removed and the local environment restored to its original condition. Pumps, wells, docks, storage areas, etc. that are

no longer in use create an environmental impact because they often prevent any natural biological process from operating. For example, a dock prevents marsh grass from growing near the interface of the open water and other marsh grass and so there is some loss of primary production. In addition, abandoned facilities often create an unaesthetic scene or "sight litter."

4) All construction activities in the parish should be closely monitored for potential environmental hazards. Because all construction is specific to a certain piece of geography, we believe that on the spot monitoring could prevent some major environmental problems from occurring. Parish residents could in some cases do this job very efficiently and, at the same time, provide for local participation.

5) New pipeline routes and navigation canals should be carefully assessed in terms of whether they are really needed or can be incorporated with other routings. If new pipelines are necessary, then restoration of the marsh should be required. If new canals are necessary, consideration might be given the prohibition of development on an equivalent parcel of land since navigation canals cannot be restored.

6) Parish officials should consult experts in regard to potential changes that might occur due to OCS-related activities that affect drainage patterns, salinity, erosion, and turbidity. Digging in the marsh usually creates a ditch and a spoil bank. Simulation studies show that the amount and the direction of water flowing over a piece of land is significantly changed as a result of a ditch or a barrier such as a spoil bank. For example, a three-sided levee around a piece of marsh 1,000 feet wide and 500 feet deep can reduce the amount of water flowing over the marsh by as much as 50 percent. Often there is no easy way to assess such changes other than by use of expert opinion and computer models that simulate the local project environment.

7) Urban and industrial developments should be avoided in unmodified areas of wetlands. The siting of new housing and industrial developments should be carefully considered. Whether and what lands should be used for development should be decided well before development begins. It might be appropriate for parish officials to classify all available land in the parish as to its suitability for development.

8) Discharge of litter and water wastes should be prevented from ships and automobiles. Besides being aesthetically objectionable, it also represents a potential cost to the parish government in that litter has to be eventually picked up and placed in another area. Water wastes represent a potential loss to the environment in that the local environment can only assimilate a certain amount of such wastes.

9) Parish officials should develop oil spill contingency plans for selected areas. It is suggested that parish officials develop their own oil-spill contingency plan. At the parish level it would be appropriate to identify those areas that are highly susceptible to offshore oil spills. Another topic for their consideration would be an evaluation of the oil spills contingency plans of private companies that operate in or off the parish. We do not suggest that individual parishes equip themselves for the task of cleaning up oil spill, only that they should plan for them and know what others have planned.

Cost Estimates of Certain Guidelines

Costs for restoration of selected pipeline canals

The volume of dirt required to fill the pipeline canals listed in Table 7 is approximately 25 x 10^6 cubic meters (33 million cubic yards). If we assume that it requires between \$.60 and \$5.00 per cubic yard of dirt, then the cost for refilling the pipeline canals listed in Table 7 would be approximately between \$70 million and \$165 million. To replant the 2,043 acres of pipeline canals would require approximately 8 man-months at \$2,600 per month or a total of \$20,800; in addition, a marsh buggy might be required at \$300/day for 1 month (total for replanting is \$27,400). Total cost estimates for refilling and replanting are as listed in Table 17. These data suggest that refilling of pipeline canals might be too expensive to consider; however, replanting seems (in selected areas) economically feasible.

Costs for assessing new pipeline and transportation canals

These costs for assessing new canals are difficult to predict, but the task might best be done by soliciting proposals for research with very specific and limited objectives or tasks so that costs can be minimized and accurately identified. We believe that these costs will not be excessive.

Table 17. Cost Estimates for Restoration of Pipeline Canals in Lafourche Parish.

1. Cost of refill dirt and transportation (2.6×10^7 yd^3)*		\$15,600,000 to \$130,000,000
2. Cost of replanting marsh grass (2043 acres)		
a. Labor	\$	20,800
b. Marsh buggy (1 mon. \$300 per day)	\$	6,600

(Replanting \$ per acre = $\frac{22400}{2043}$ = \$13 per acre)

Note: *Estimated volume of dirt needed to refill pipeline canals in Lafourche Parish as listed in table 9. We have a cost range of between \$0.60 to \$5.00 per cubic yards of dirt. Calculations are as follows:

(3.1928 sq miles) (2.7878×10^7 sq ft per sq mile) (8 foot depth)

$\div$ (27 cubic feet per cubic yard) $\cong 2.6 \times 10^7$ yd^3.

(2.6×10^7 yd^3) (\$0.60) = \$15,600,000

(2.6×10^7 yd^3) (\$5.00) = \$130,000,000

Costs for expert advice

Expert advice will probably have to be solicited on an individual project basis; some aid could be obtained from university faculty, however, some private companies do have some of the necessary expertise. We believe that these costs will not be excessive especially if the tasks are tightly defined as suggested above.

Costs for a contingency plan
of oil spill in parish

We suggest that parishes identify and familiarize themselves with those areas that could be subjected to a potential oil spill; for example, in Lafourche Parish most of the marsh below Golden Meadow could be subjected to an offshore oil spill. In addition, it might be appropriate that they formulate a plan for an oil spill and then evaluate such plans that private companies operating from Lafourche Parish have in regard to an oil spill. Consideration should be given to requiring all companies to have a contingency plan for an oil spill in the parish. A means of periodically checking the effectiveness of such plans might well prevent major damage from occurring as a result of an oil spill. If a parish contingency plan for oil spills follows this approach, then no costs should be incurred other than the salaries of the existing officials while they are doing this planning.

Cost for removal of abandoned facilities

We are unable to estimate these costs. They will vary for each individual, project, company, and location.

Cost for environmental monitoring in parish

We believe that a variety of low-cost alternatives are available for implementing the environmental monitoring of a parish. For example, retired people could perform this task very well and possibly, as a result, renumeration could be minimal or no cost at all. We do not advocate an agency for implementing this guideline. We only advocate that local residents be aware and become involved in the monitoring of environmental impacts of OCS-related activities.

The cost of OCS activities as related to air and water quality can be calculated on the basis of how much it cost industry to clean the air and water it uses. For example, it is estimated that primary treatment of water costs approximately \$.10 per 1,000 gallons of water used; secondary and tertiary treatment can cost approximately five times as much. The costs of purifying air can be similarly calculated but the data were not available to us.

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APPENDIX A
OFFSHORE FACILITY SITING AND ABANDONMENT

If commercial quantities of oil or gas are found during the exploratory drilling, additional wells must be considered to find the extent and capacity of the field. A development plan must be formulated and submitted to the Federal authorities for approval. This plan includes: (1) a detailed description of drilling vessels, platforms, and structures, showing their planned locations as well as their major features; (2) the location and number of wells to be drilled including the bottom hole location for directional wells; (3) the structural interpretations of the area; and (4) any other data the supervisor deems necessary. Decisions concerning production facility types, pipeline facilities, and new onshore support facilities must be made. A separate drilling permit, identical to that required for exploratory drilling, must be requested. The development plant and drilling permit are subject to a thirty-day review period established by the Department of the Interior (Kash et al. 1973).

A sample development plan follows.

EXAMPLE OF A TYPICAL
LEASE PLAN OF DEVELOPMENT

Subject:
1975 Lease Plan of Development
Lease OCS-G 0000
South Timbalier Block 1100 Field
Offshore Louisiana

District Supervisor
U.S. Geological Survey
Houma District
Post Office Box 1269
Houma, Louisiana 70360

Dear Sir:

This is our application for approval of the 1975 plan of development scheduled for lease OCS-G 0000, Block 1100, South Timbalier Block 1100 Field, offshore Louisiana. A 24-slot platform (Platform A) is scheduled for installation during April 1975, and will be located 8500 FWL and 5000 FNL of Block 1100. Drilling operations will start in June 1975, and it is anticipated that eight wells will be drilled this year.

The development wells are designed for primary production from known producing horizons, but in addition, six water-injection wells will be drilled. The injection wells will allow an early initiation of pressure maintenance in order to enhance recovery operations in the "D" sand. This letter is intended to serve as a Plan of Development and as a request for approval of waterflooding operations.

Our company acquired lease OCS-G 0000 at the September 1974 Federal Lease Sale for a total bonus of 150 million dollars. The 5000-acre block is located 50 statute miles offshore in an average water depth of 175 feet. We acquired the offset lease to the north in an earlier lease sale and it has now been extensively developed with a current production rate of over 50,000 barrels of oil and 50 million cubic feet of gas per day. The hydrocarbon accumulations believed present in Block 1100 represent downdip southward extensions of known producing zones. A structure map of the area is attached (Fig. A1).

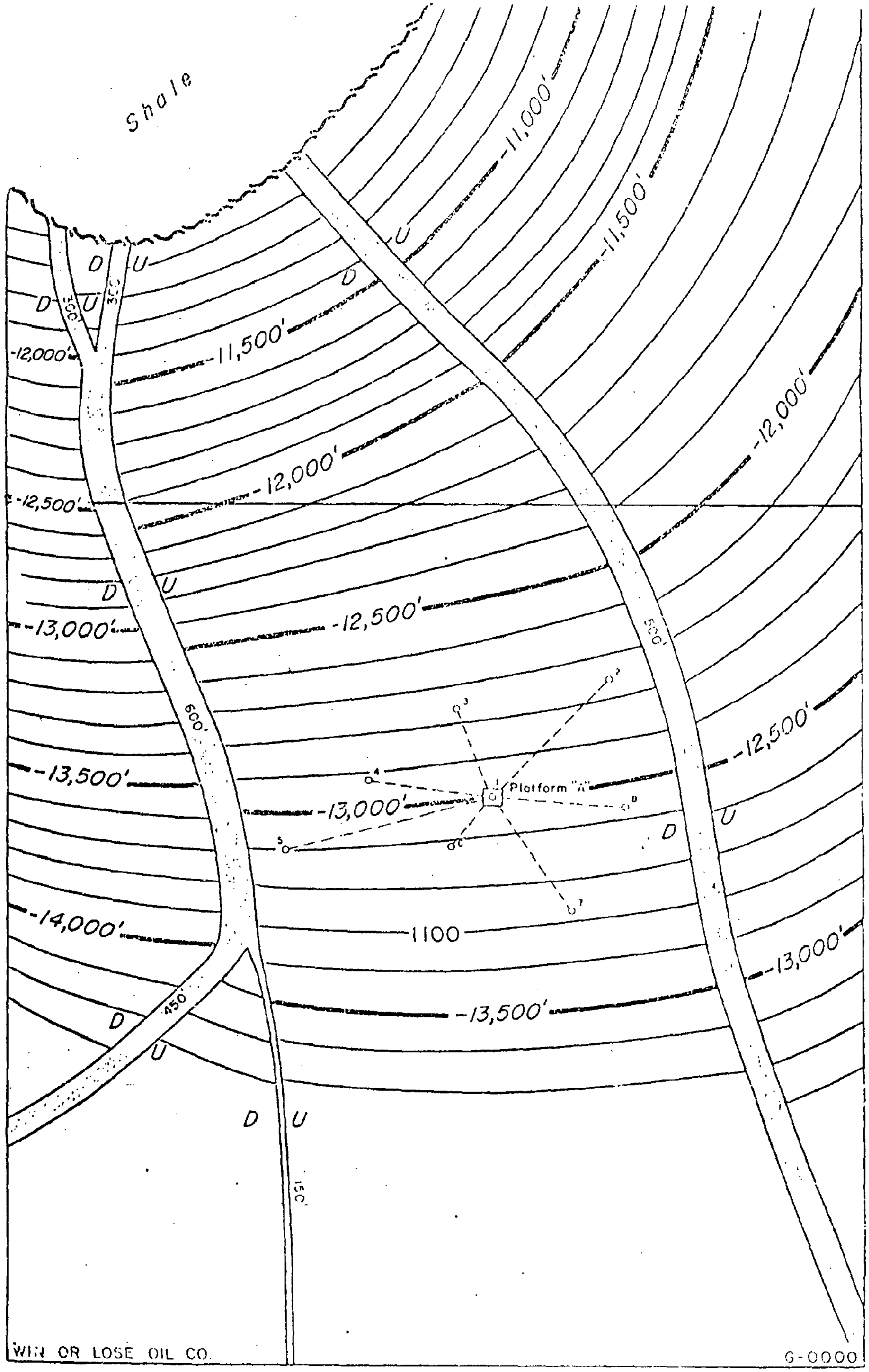
The productive section is Upper Miocene with shallowest pay near the Pliocene-Miocene contact at about 10,500 feet. The basal pay, the "F" sand, is productive near the shale intrusive at 13,500 feet. The field has two pays, the "D" and "E" sands, which contain most of the proven reserves. The "D" sand is the primary objective on the new lease. Top of mild geopressures, 11.0 ppg mud weight, occurs about 50 feet above the "D" sand. The shale intrusive contains hard geopressures, but wells will be designed to avoid penetration of the shale and to stop drilling if mud weights become too high.

The first four wells from the "A" platform will explore for the "D" sand water level so that water injectors can be drilled early in the program. The first well, A-1, will be drilled to test the "F" sand at an optimum location. All wells will be located within the new lease boundaries. The "D" sand wells should require mud weights of no more than 11.0 to 11.2 lbs/gal. The "F" sand probably will require a mud weight of 14.0 to 14.5 lbs/gal. Protective casing will be set through the "D" sand before drilling the "F" sand.

The plans we present for the development phase are consistent with requirements to minimize fixed and temporary structures necessary for exploration, development, and production of the leasehold. Use of a single permanent structure will have a minimum effect on other significant uses including commercial fishing, and no reasonable alternative placement would cause less interference.

Pollution containment and removal equipment are available as required under the auspices of Clean Gulf Associates. Quick response units and spill containment supplies and equipment, all located nearby, constitute a capability exceeding minimum requirements necessary to stop or retard a spill. We feel the lease can be safely developed within existing standard practices and operating regulations without significant danger to the resources involved. The Geophysical-Archaeological Survey for possible cultural resources will be conducted within the next few days, and the report will be sent to you.

The plan as described above consists of the drilling of eight wells including two "D" sand water-injection wells during the upcoming development period through December 1975. Your consideration and approval of this plan is requested.



SOUTH TIMBALIER BLOCK 1100 FIELD
ABNORMAL PRESSURE ZONE
CONTOUR INTERVAL = 100'
SCALE 1" = 2000'

Fig. A1. Structure map of the area for sample development plan.

Facility Abandonment

When production operations cease and a well is classified as "inactive," plugging operations must be completed within a specified time period. The Louisiana Department of Conservation is the state agency that issues the procedures to be followed in plugging and abandoning a well (La. Dept. of Conservation 1974).

After obtaining a work permit from the District Manager (from the Division of Minerals) the appropriate Oil and Gas Inspector must be notified, at least twelve hours before operations begin.

In plugging wells, sufficient cement is used to isolate each perforated pool. Cement plugs or retainers are used to plug the wells. The dimensions of each plug and the depth to which it is placed is determined by considering certain factors such as whether the production casing has been removed from the well, whether the perforated liner can be easily removed, and whether fresh water horizons have been exposed. Additional plugs are placed to adequately contain any high pressure oil, gas, or water sands. On top of the well, a thirty-foot cement plug (minimum) is placed, and mud-laden fluid of not less than nine pounds per gallon is placed in all portions of the well not filled with cement.

All cement plugs are placed by the circulation or pump-down method unless otherwise authorized. On water locations, the casing must be cut a minimum of ten feet below the mud line. The only exception to cutting off the casing arises if the operator contemplates reentering the well at some future date for saltwater disposal or other purpose. In this case, the District Manager will not enforce the rule of cutting the casing below mud depth.

For temporary abandonments, the well must be mudded and cemented as if for permanent abandonment; only the surface cement plug is not mandatory. Along with the plugging of the well with cement and the cutting of the casing below the prescribed mud depth, foundations, tanks, batteries, and all other material and equipment used at the well are salvaged for reuse or for sale as scrap. Because the oil companies are not allowed to bring in any material for fill purposes (personal communication, R. R. Hickman, Exxon Environmental Conservation Manager), any canals which were dug are plugged to help prevent saltwater intrusion since the previously excavated material is never enough to fill the channel. The plants constructed to process, refine, and store the hydrocarbons are left standing.

APPENDIX B

STATEMENT OF DR. LYLE ST. AMANT, ASSISTANT DIRECTOR FOR MARINE FISHERIES AND COASTAL MANAGEMENT, LOUISIANA WILDLIFE AND FISHERIES COMMISSION, BEFORE THE AD HOC SELECT COMMITTEE ON OUTER CONTINENTAL SHELF, U.S. HOUSE OF REPRESENTATIVES:

Mr. Chairman, members of the committee, my name is Lyle S. St. Amant....My statement for the sake of brevity, will be addressed to two principal points. One, a brief history and explanation of the fisheries-petroleum interaction in Louisiana; and two, some evaluation of certain environmental sections of H. R. 6218.

1) The history of petroleum production in Louisiana and its effect on the coastal ecosystem probably represents to a maximum degree those types of experiences that might be expected in any marine petroleum-producing area in the world. I feel that this position can be taken for these reasons:

a) Petroleum has been produced in the estuaries and wetland areas of Louisiana for fifty years and offshore since 1937. In this area there are now 25 to 30 thousand producing wells and approximately 38,000 miles of pipelines.

b) Environmental regulations and management was nonexistent during the initial twenty years of production. In the early years and during World War II, practically every accident and/or type of mismanagement, vis-a-vis petroleum production in a marine environment, probably occurred in Louisiana.

c) After fifty years of exposure to oil production, we have no evidence that the fishery production of Louisiana has declined or is significantly different from production in early years. Louisiana now produces as much as 1.2 billion pounds of commercial fish annually or 23 percent of the total U.S. fishery production. From this, it is reasonable to assume that even under the worst conditions and long exposure, it is not likely that marine productivity will be totally destroyed or even materially altered. Therefore, there is adequate opportunity in new areas of exploration to determine the nature of impacts and to take corrective steps as we have done in Louisiana since 1950.

2) The fact that oil production apparently has little effect on fishery production does not rule out numerous administrative, regulatory, and environmental problems that must be evaluated and overcome, if an orderly multiple use of the marine area is to be experienced, and if the basic equilibrium of the ecosystem is to be maintained. The coastal management procedures developed by Louisiana since 1950 require an extensive knowledge of the biological processes and ecosystem dynamics of the area and the population dynamics of certain key species. It also requires that regulations be promulgated by an agency competent in ecosystem analysis and be based on significant quantitative data represented by long-term studies.

3) Environmental factors, to a large extent, fall into several categories that should be studied and evaluated separately. These include:

a) Oil pollution from accidental spills or chronic sources. Our experience indicates that the toxic effects of oil to a large extent has been exaggerated and animal, plant, and fish kills are negligible. Recovery of stressed areas usually occurs in a reasonable length of time, but the cost of cleanup, public outcry, and emotional upheavals may be considerable.

b) Amore complex environmental problem involves disruption, temporarily or permanently, of shallow water and wetland ecosystems and shore lines of navigation and dredging procedures necessary to transport oil-drilling rigs to their sites and the installation of pipelines from these sites. Operations in such estuaries need rigid regulations, but suitable methods governing multiple use therein is possible if adequate knowledge of the area is available and sufficient authority is granted for surveillance and enforcement of the operations.

4) Basically, oil production in the marine system falls into two broad categories: Production in offshore deep waters and production involving the coast and shallow-water estuaries.

a) The offshore problems are minimal—since equipment is floated in place, dredging is not required; all operations are from a central platform; fail-safe equipment is maximal; and surveillance and enforcement is easily attained. The presence of the structure itself has no significant ecological effect and frequently is beneficial as an artificial reef.

b) Offshore problems involve: (i) Occasional spills or pollution which has not proved to be significantly toxic; (ii) Navigational problems and restrictions of commercial fishing areas if platforms are improperly placed or are too dense. (iii) Sea-floor clutter and well stubs if not controlled.

c) Inshore problems are more complex as listed above but are not insurmountable provided a thorough knowledge of the ecosystem is available.

5) It is our experience in Louisiana that production in offshore areas beyond fifteen miles rarely impinges on the coastline excepting as a result of pipelines coming from that area. I know of few if any instances where oil spills occurring significant distances offshore resulted in serious involvement of beach areas or marshlands. Generally, clean-up procedures can be instituted before its arrival at the beach and biodegradation or breakup of the spill reduces the probability of large coastal areas being affected.

With respect to specific comment on H. R. 6218: A single environmental assessment will not suffice to determine if impacts are occurring in the system. Fishery production and energy sources in the ecosystem are constantly cycling as a result of normal seasonal and annual environmental parameters. In some cases, as demonstrated in Louisiana, the seasonal stresses may far overshadow incipient long-term changes from pollution, if any, from the accumulative effects of dredging and water changes in the system. It has taken Louisiana nearly fifteen years to develop the hydrographic patterns, the temperature variations, river flows, and rainfall analysis, to be able to predict the annual expected production of shrimp, oysters, and menhaden.

Without knowing the extremes of fluctuations in a normal system and the factors controlling such fluctuations, it would be impossible to determine the effects of an oil spill or dredging activities with any degree of accuracy. If for example, we had not had this type information at the time of the Chevron and Shell oil fires in Louisiana to evaluate the effects on fish production, it is probable that the amount of litigation would have been monumental. It is imperative that the managing agency, whether it be federal or state, operate on a continuous basis so that in the event of an accident or some other type of environmental stress, it can be determined whether a decline in a particular species of animal is a result of the incident or a natural occurrence. Failure to establish this type of monitoring will result in a faulty management and regulation of the ecosystem....

States should be given a major role in regulating the activities of OCS petroleum production that traverses state boundaries. This calls for a high degree of management and regulatory procedures based on research and data gathering of a continuous basis. It is not clear which state agency would be involved in undertaking this procedure through the Coastal Zone Management Program. Logically, the marine fishery agency should be in a better position to carry out such work.

And finally, I see no mention in the bill of two major factors associated with petroleum production. One, how will chronic pollution be controlled and managed; and two, what provisions are being made to clean up depleted areas and return them to a natural condition. It is my experience that the older the oil field becomes, and as it approaches depletion, the greater becomes the environmental problems and the less likely are we to find the lessees anxious to comply with and finance the necessary corrective measures.

APPENDIX C

OVERVIEW OF SALES AND SERVICES

The offshore oil industry is complex. There is a diversity of companies involved in support of oil companies involved in search for and production of oil and gas in the outer continental shelf region. Similarly, there is a diversity of companies involved in sales and service of supplies and equipment necessary for drilling wells and bringing the minerals ashore.

Support companies can be divided as follows: (1) transportation support companies; drilling contractors, and rig owners; (3) construction and fabrication support; (4) geophysical support companies; and (5) diving contractor support companies.

These categories can be further divided. For example, transportation companies include workboat owners and operators, helicopter companies, and a few companies that provide hydrofoil and air cushion type behicles. The boat companies include operators of crew boats, which transport men to the rigs and production platforms; tugboats, to tow rigs and barges; and supply boats, which transport the necessary supplies to the drilling and production sites. Helicopter service is generally limited to providing crew transport, or to transport important pieces of equipment in emergency situations. Air cushion vehicles are still in experimental usage at this time.

Drilling contractors can be divided further into those contractors owning offshore drilling equipment (mobile rigs, fixed platform rigs, tenders) or with drilling crews working offshore; oil companies who own their own equipment for offshore drilling; and offshore workover companies, who own and operate offshore workover drilling-type rigs.

Construction and fabrication include companies that: lay offshore pipelines, install offshore platform or other offshore oil structures, fabricate offshore platforms or other offshore oil structures, package drilling or production platform facilities, build mobile drilling units or derrick and pipelaying barges; naval architecture and marine engineering firms should also be included.

Geophysical contractors are those companies that contract to collect offshore seismic information for oil companies. There are several oil companies that have their own geophysical boats and crews, including Shell Oil Company, Gulf Energy and Minerals Co., Texaco Inc., Mobil Oil Corp., and Exxon Co. USA.

Diving companies are those providing diving service, as well as those that own submersible work vessels and those with saturation diving systems.

There are too many sales and service companies to mention in this brief section. However, major selected sales and service companies include: drilling fluid and mud service; catering service; cementing, logging, and perforating service; wireline service; and fishing tool service. There are scores of other service-type companies including such services as electrical work, air conditioning/refrigeration work, and sand blasting/painting work.

Sales and service companies, for the most part, sell supplies that are necessary for drilling an oil or gas well, for completion, and for production and transport ashore. Most of the sales companies also offer service crews to provide for proper use of the supplies they are involved in selling.

There is one other type of service company that we must also mention--environmental clean-up service companies. They are involved with the clean-up and protection of the environment in those cases when there has been an oil spill from a blow-out or a pipeline rupture.

In Lafourche Parish, from Lockport to Grand Isle, we can identify 55 firms that offer sales and services of supplies, equipment, tools, and the like.

Additionally, 14 oil companies have offices and facilities, such as warehouses and storage facilities in Lafourche-Grand Isle. Also, there are 45 barge, boat rental, or towboat service companies listed from Larose to Grand Isle. Finally, there are 19 shipbuilding and repair yards from Lockport to Grand Isle.

The impact of these facilities in terms of altered land use, water use, and waste disposal should not go unnoticed.